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REPORT OF THE CHIEF OF THE BUREAU OF ENTOMOLOGY

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., August 31, 1929.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1929.

Respectfully,

C. L. MARLATT,
Entomologist and Chief of Bureau.

Hon. ARTHUR M. HYDE,
Secretary of Agriculture.

DECIDUOUS-FRUIT INSECT INVESTIGATIONS

Investigations of deciduous-fruit insects have been carried out under the direction of A. L. Quaintance, as formerly.

CODLING MOTH

Studies on the codling moth have been continued in the main along lines reported last year and have related especially to the spray-residue problem. Further information has been obtained concerning certain important points on the habits of the codling moth in orchards, especially the influence on the insect of climatic and other conditions. It has been found that activity of the moths in the spring is greatly retarded by cool weather, and that oviposition does not take place to any extent until the evening temperature is between 55° and 60° F. It also appears that cool temperatures during incubation of the eggs may reduce the vitality of the resulting larvæ, so that the poison used for first-brood spraying is more effective. Light winds have the effect of immobilizing the adults. Thus, in the laboratory an artificially produced 6-mile breeze directed upon adult moths resting on twigs caused them to remain there for four days without apparent movement. Further work will be necessary to determine whether the influence of winds is, perhaps, as important as that of temperature in controlling oviposition, particularly of the first brood, and what velocity of wind would be required to hold the moths quiet under natural conditions in the orchard. Along with the foregoing observations made at the Wichita station, where the work is being conducted cooperatively with the Kansas Agricultural Experiment Station, studies have been made that should help to explain variations in moth abundance in different parts of an orchard, or even on different trees in the same orchard subjected to essentially the same insecticidal treatment.

The effects of low temperatures, artificially produced, on the overwintering larvæ of the codling moth were studied during the winter of 1928–29. All temperatures were recorded by the electrothermal method by means of self-recording pyrometer and thermocouple. The lowest minimum temperature of the insect chamber from which any larvæ survived was —45° F. Some larvæ survived in various tests when the insect chamber recorded —43.5°, —41°, —29°, —26°, —18°, and —17°. One lot of larvæ was suddenly changed from a temperature of

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—45° to 45°, and another lot from 42° to —29°. Three individuals survived the first treatment and two individuals the last. Such information is of value in forecasting the probable effect of winter-weather conditions in orchards on codling-moth abundance the following season.

As last year, extensive tests have been carried out in orchards with various materials to determine their value for codling-moth control and as possible substitutes for lead arsenate. Such work has been under way principally at Yakima, Wash., Wichita, Kans., and Vincennes, Ind.

At the Yakima station rather promising results were obtained with cuprocyanide, cryolite, and the fluosilicates of barium and potassium, whereas aluminum arsenate and zinc arsenate, even when used with an adhesive such as fish oil, were inferior to lead arsenate and were difficult to remove from the fruit. It was found that the use of an excessive quantity of lime with lead arsenate reduced the arsenical residue, though probably this reduced also the control value of the poison. The substitution of oil emulsion for lead arsenate in most of the cover sprays again resulted in poorer control with oil throughout. Nicotine sulphate in combination with oil or other materials showed some promise of being a useful substitute for lead arsenate. In the laboratory it was found that nicotine sulphate destroyed about 50 per cent of the eggs of the codling moth. Ten or more days is required to destroy eggs subjected to such low temperatures as are usual in cold-storage houses. Beginning with the spring of 1929, experiments were started to determine the value as a spray of oil in combination with nicotine, pyrethrum, Derris, and also with nicotine combined with various other materials. The most active principle of Derris, rotenone, is being tested, and more comprehensive tests are under way with cupro-cyanide and with certain fluosilicates. Some of this work is being done in cooperation with the Bureau of Chemistry and Soils.

At the Wichita, Kans., station many tests of materials as substitutes for lead arsenate were made in a 25-acre apple orchard. None of these materials gave results in codling-moth control equal to lead arsenate at 1½ or 2 pounds to 50 gallons of spray. Zinc arsenate gave the next best results, though these were far from satisfactory. Aluminum arsenate and calcium arsenate as well as oil sprays were of less value than zinc arsenate. The best control was obtained with lead arsenate in the proportion of 1½ pounds to 50 gallons of water, plus 1 pint of fish oil. On this plat worminess amounted to about 2.5 to 3 per cent for the season. The residue was very heavy on the fruit, but it was not difficult to remove it by wiping.

At the Vincennes, Ind., station many stomach poisons and contact insecticides were tested on a laboratory basis. Zinc meta-arsenite showed a toxicity equal to or greater than lead arsenate, but unfortunately was injurious to apple foliage. Under laboratory conditions barium fluosilicate, potassium fluosilicate, and cryolite continued to prove of value, but results were much inferior in the field. Cuprous cyanide showed a rather high toxicity, nearly equal to that of lead arsenate, but caused some spray injury when used alone. Furthermore, it is incompatible with lime-sulphur, and thus can not be used with this material, nor can it be used with Bordeaux mixture. As previously learned, casein-lime spreaders proved not to enhance the effects of lead arsenate when used at strengths greater than one-eighth pound to 50 gallons. Fish oil used as an adhesive slightly increased the efficiency of lead arsenate. Tests indicated that Bordeaux mixture and lime-sulphur impaired seriously the efficiency of lead arsenate. Certain nicotine compounds do not long retain their toxicity, perhaps not longer than one or two days after application. The addition of sodium bisulphate and aluminum sulphate to nicotine sprays, although beneficial, is attended by serious danger of spray injury. Glycerine added to free nicotine increased its efficiency and lengthened its period of usefulness. Nicotine tannate showed considerable promise. The sodium oleate-oleo-resin of pyrethrum spray, as developed at the Japanese-beetle laboratory, showed the highest toxicity of all the pyrethrum compounds tested. Its value under field conditions remains to be determined. Field tests were carried on with lead arsenate, zinc arsenate, and aluminum arsenate, all of which gave satisfactory control under the conditions of light infestation in that section. The addition of white oil or fish oil to the arsenical, or the use of oleated lead arsenate, did not seem to result in any improvement. Barium fluosilicate, potassium fluosilicate, and cryolite, used with fish oil, proved valueless, the cryolite

plat being not much better than the check. Cuprous cyanide was found to be almost as effective as lead arsenate.

Further information has been obtained on the practicability of using the chemically treated, so-called automatic, codling-moth bands. These bands, impregnated with a mixture of beta naphthol and red engine oil of paraffin base, are placed around the trunk and larger limbs of trees, and under them the larvæ spin up to pupate. They were tested in cooperation with a number of entomologists over a considerable range of territory. Four types of bands were used, namely, those made of single-faced corrugated paper, those made of crêpe paper, those made of burlap, and those made of cheesecloth. The chemically treated corrugated-paper bands appear to be the most practical, as they harbor the most larvæ, give the greatest percentage of kill, do not endanger the health of the trees, and are inexpensive. Satisfactory results were obtained with bands treated with 1 pound of beta naphthol and 1½ pints of red engine oil. It would appear that this formula may be adopted as the standard for band treatment. Some of the toxic coating may be removed by heavy rains, but it is believed that this difficulty can be satisfactorily overcome by adding a metallic soap, such as aluminum stearate, to the standard formula. Although there has been some variation in the results reported by different experimenters in the use of these chemically treated bands, the reports in general are favorable. Experience has now been sufficient to indicate their usefulness in automatically destroying the larvæ which spin up under them, usually about one-third of the larval population of the trees.

ORCHARD INSECTICIDES

Fundamental investigations of insecticides for orchard and other uses have during the past few years been arranged largely to bear on the spray-residue problem. During the year a method has been perfected for determining the minimum lethal doses of dry powdered stomach-poison insecticides for a laboratory-test insect, the silkworm. This so-called "sandwich method," which will be described in Anzeiger für Schädlingskunde, has been used to determine the absolute toxicity of a number of stomach poisons, including acid lead arsenate (used as the standard of comparison), basic lead arsenate, aluminum arsenate, manganese arsenate, copper cyanide, copper thiocyanate, various fluosilicates, potassium iodate, calcium iodate, potassium periodate, nicotine tannate, diphenyl, and rotenone. This method of determining the lethal quantities of poison will be used in the bureau's cooperative work with the Bureau of Chemistry and Soils in the development of new insecticides, especially the derivatives of rotenone, various synthetic compounds similar to nicotine tannate, pure nonlead arsenicals, etc. Attention is being given to the toxicity of stomach poisons administered directly through the mouth to newly hatched codling-moth larvæ by means of a micromanipulator. The absorption, distribution, and elimination of lead in insects is being investigated by the radioactive-indicator method.

Improvements are being made in methods for determining the relative toxicity and intimate action of contact insecticides. It appears that the immersion of aphids in solutions yields dependable results. By a study of the rate of recovery of the insects and of the speed of lethal action, it has been possible to determine with an indicator and to differentiate the effects of closely related materials. The relative lethal persistence of various preparations, such as nicotine, rotenone, and pyrethrum, on different surfaces is being given attention. Newly hatched codling-moth larvæ are made to crawl across these surfaces at various intervals of time after the spray has dried.

The insecticide-information service has been maintained and strengthened and a large up-to-date bibliography on insecticidal materials throughout the world is available. It consists of about 20,500 cards, representing about 17,000 distinct references. Effort is being made to keep this bibliography up to date, and it is being utilized in the preparation of papers on various insecticides. The first paper of the series is now being prepared and will cover the halogen derivatives of benzene, paradichlorobenzene being the most important compound of the group.

PEACH INSECTS

As in former years, extensive orchard tests have been made at the Fort Valley, Ga., laboratory of various spray and dust formulas for the control of the plum curculio under southeastern conditions. The infestation by this insect during 1929 in Georgia, and in the South generally, has been the heaviest since 1921. This has resulted

in part from the large quantity of wormy fruit left in orchards in 1928, and in part from the mild winter of 1928–29. Furthermore, the insect was able to get a fairly early start this spring, and there has been time for development of a very considerable second brood. In addition to experiments designed to determine the control value of various dusting and spraying combinations and times of application, attention has been given to tests of different types of spraying and dusting apparatus.

Attention has been given to ways and means of preventing, if possible, arsenical injury to peach foliage. Ferric oxide and lead acetate were found to be most valuable for reduction of this burning, although some foliage injury resulted when the latter chemical was used. Various fluosilicates have been under test as substitutes for lead arsenate, especially to determine their effect on peach foliage. Of those tested, potassium fluosilicate in the proportion of 2 pounds to 50 gallons of water caused less injury to the foliage than did lead arsenate. Under field conditions, however, the use of this material as indicated was followed by defoliation of trees due to bacterial leaf spot, and the work was abandoned.

The lesser peach borer, which infests the trunk and larger limbs and crotches of the peach, has been the subject of special experiment in view of its prevalence and damage to peach orchards in the Southeast. It was found that when paradichlorobenzene dissolved in cottonseed oil was applied with a brush to the infested areas the larvæ were quickly killed without injury to the trees. Although further studies will be made with this treatment, it is now felt that it is safe to recommend it for general use. The employment of this material in paint form will prove useful, it is believed, against various other insects of similar habits.

The oriental peach moth did its first commercial damage to peaches in the southern Indiana section during the season of 1928. Here some of the late varieties were almost 100 per cent infested. The experimental work undertaken in the spring of 1929 involved considerable testing in orchards of various sprays and dusts, especially heavy applications of lime and talc, the use of which, according to some investigators, interferes with the successful oviposition of the moths or the movements of the larvæ on the trees. At the Vincennes, Ind., laboratory work is being done on the use of bait traps, repellent materials, the determination of the parasite fauna of the peach moth, banding, and studies of the overwintering habits of the larvæ. Special investigation of the parasites of the peach moth, however, is centered at the Moorestown, N. J., laboratory. In addition to studies of local parasites, material is being obtained from as much of the infested region in this country as possible in order to determine what native species are attacking this insect as it spreads into new regions. Although the home of the peach moth is not definitely known, the insect has been present for some years in different localities in Europe and has been recorded from Australia. On account of the difficulty of controlling the peach moth by the usual spraying methods, the utilization of parasites becomes extremely important, and foreign countries should be thoroughly searched for these with as little delay as possible.

NUT INSECTS

Work on nut-infesting insects is divided into two distinct projects, namely, insects affecting the pecan, and those affecting chestnut, walnut, etc. Headquarters for the latter project are at French Creek, W. Va.

The rapid disappearance over wide areas of the native American chestnut, due to the chestnut-blight disease, has led to an interest in extensive plantings of the more or less blight-proof species of chestnuts from Japan and China. This program is seriously hampered by the prevalence of nut weevils, which destroy American-grown nuts for seed, and nuts grown in orchards for home and market purposes. Investigations have been made in a considerable number of orchards of Japanese and Chinese chestnuts to determine conditions which bear upon loss from these weevils. Experiments with various arsenical sprays and dusts have, unfortunately, shown no beneficial results. Tests are under way to determine the value of picking up all nuts as fast as they ripen and so handling the crop that weevils will not be able to escape and enter the soil. It is hoped that by this method chestnut growers, by exercising vigilance, will be able to effect a reduction of this pest so that a reasonable crop of sound nuts can be secured. In connection with the biologic studies, information is being obtained on the natural enemies of nut weevils in the hope that means may be found for their more effective use. Experiments to determine the effect of orchard cultivation on the insects undergoing

transformation in the soil have shown but little benefit thus far, owing to the considerable depth to which the grubs of these weevils penetrate for pupation. Tests with soil fumigants have been made, but must be repeated before conclusions can be announced.

Investigations of pecan insects in the South were continued in the main along lines under way the preceding fiscal year. The principal laboratory is at Albany, Ga., and there are three sublaboratories situated in districts where special investigations can be most advantageously pursued. Thus, one is located at Brownwood, Tex., for a study of insects destructive to native as well as cultivated pecans; another, recently established at Shreveport, La., will concern itself with pecan insects injurious in that general section; still another, at Experiment, Ga., is giving special attention to certains pecan borers and the nut weevil.

At Albany, Ga., a comparison was made of the methods of applying poison dusts against the pecan leaf case bearer by airplane and by ground machines. In the applications by airplane cooperation was obtained from the cotton-insect division of the bureau and from the Bureau of Plant Industry. Five applications to a sizable pecan grove were made for the simultaneous control of pecan scab and the leaf case bearer. The flying was done at a speed of from 95 to 100 miles per hour. The swath widths averaged about 47 feet or approximately the distance between the tree rows. Four airplane loads, or 2,000 pounds of dust, were applied in each dusting, making an average of about 3.8 pounds of dust per tree, or 76 pounds per acre. The dust cloud discharged from the plane used in the tests followed a spiral course and showed a decided tendency to rise and remain above the trees for some distance beyond the path of flight of the plane. Gradually, however, it settled, some six or more rows away. A careful check on the results of this dusting as determined by the abundance of the insect on treated and untreated trees indicated no appreciable difference between the results with poison applied by airplane and those with poison applied by ground machines. Until opportunity is afforded for conducting additional experiments with the airplane in pecan dusting it is felt that no recommendations from the insect-control standpoint are justified.

Extensive tests were made against the pecan leaf case bearer by dusting with ground machines to determine the best materials and the best times to make applications to obtain maximum control. Work was done on some five or six different properties. Best results were obtained from two applications of dust composed of monohydrated copper sulphate 20 per cent, lead arsenate 10 per cent, and hydrated lime 70 per cent. In a comparison of homemade and factory-mixed dusts the latter gave the better control. Aluminum sulphate, when used with lead arsenate, showed no superiority to monohydrated copper sulphate. Very good results were obtained with Paris green used with monohydrated copper sulphate and hydrated lime, and there was no injury to the foliage of the plant. Calcium arsenate gives promise of being a suitable insecticide for the pecan, and used at proper strength it did not endanger the foliage.

In addition to the field work under way at Albany, Ga., a good deal of time has been devoted to biologic studies, particularly of the hickory shuck worm, which is attracting more and more attention on account of its injuries. Local damage by Phylloxera in pecan nursery trees has necessitated observations on this insect, which will be seriously studied at the first opportunity. Work has been started looking toward the utilization of parasites of pecan insects, in view of the difficulty in general of insect control on trees of such large size as the pecan. Parasites have been reared from most of the common species and information concerning these is being obtained.

At the sublaboratory at Experiment, Ga. (recently transferred there from Barnesville, Ga.), attention has been given especially to the life history and habits of the pecan weevil, which in that general section is quite injurious. Studies on its life cycle have been pretty well completed, and observations have been made concerning the behavior of the larvæ in the soil, as well as on the time of appearance of the adults on the trees. Experiments are under way to determine the effect on the grubs and the immature adults in their cells in the earth of soil cultivation and of soil fumigation. The possibility of killing the adults with arsenical sprays or dusts has been investigated, but no treatment of special promise has thus far been found.

At the Brownwood (Tex.) sublaboratory, in addition to considerable experimental work with dusts and sprays for the control of the pecan-nut case

bearer, the staff is specializing on the parasites of the more important pecan insects of that district, in view of the impracticability of the use of artificial means of control on large, wild pecan trees growing in the river bottoms and elsewhere, from which so large a part of the Texas crop is produced. Cultures are being made of the egg parasite *Trichogramma minutum* Riley for use against the nut case-bearer and other species.

The assistant at the laboratory established about January 1 at Shreveport, La., has spent most of the spring in survey work in order to become familiar with the more important pecan insect pests of that district. Injuries here by certain species of May beetles and by the pecan shuck worm have been investigated and biologic and experimental control work undertaken.

BLUEBERRY MAGGOT

There has been little change in the general situation with regard to the blueberry-maggot problem in eastern Maine since last year. Growers who cooperated in the bureau's experimental dusting involving considerable areas of blueberry barrens were pleased with results and have equipped themselves with machinery and materials for effective control work. Experiments continue to show the efficiency in blueberry-maggot control of calcium arsenate dusted over the plants. One application of dust in early July effected a reduction in maggots of 62.69 per cent, and two applications a reduction of 89.6 per cent, as compared with the number in the untreated check plat. The topography of the blueberry barrens is such that the question arose as to whether dust could be economically applied by means of the airplane. Under special provision by Congress applications of dust by airplane were made by a commercial firm in July. An average of 6.61 pounds of dust per acre per application was made to most plats. The average benefit from all plats receiving two applications was a reduction of 82.86 per cent in the number of maggots. The cost of the application of dust by airplane greatly exceeded that by ground machines, but this cost would be reduced if the area treated were enlarged.

Considerable time has been given to obtaining as full information as possible concerning the biology, habits, and ecology of this insect, which in reality is the common apple maggot, and it is believed that another season's work will permit of the preparation of a complete report on the subject with practical recommendations for its effective and economical control.

GRAPE INSECTS

Work on grape insects at the Sandusky (Ohio) laboratory has been limited to vineyard experiments to develop a spray schedule which will obviate arsenical-spray residues on the harvested fruit. The necessity for late spraying is due largely to damage in midsummer and later by the grapeberry moth, which in the northern Ohio district is very injurious. Much of this work has paralleled activities with a similar objective on apple. Many possible substitutes for lead arsenate have been tested under vineyard conditions, including many arsenicals, fluosilicates, various plant extracts, and the like, but none have proved equal to lead arsenate. In cooperation with the officials of the Bureau of Chemistry and Soils at Cincinnati, Ohio, detailed information has been obtained on the quantity of poison present on harvested fruit following application of various poisons. Unfortunately, in the experimental-vineyard blocks where control of the second brood of the grape berry moth has been secured, the ripening fruit has in a majority of instances shown arsenic in amounts considerably greater than 0.01 grain per pound of fruit, some samples running as high as 0.07 grain per pound or above. Vineyardists are therefore forced to confine applications to the first brood of berry-moth larvæ. In heavily infested vineyards this has resulted in serious loss. Very thorough spraying against the first brood, followed by applications of nonarsenical materials for the second brood, obviates the residue difficulty, but control of the insect has not been entirely satisfactory. Further attention will be given to this situation, and it is hoped that unobjectionable and effective sprays can be developed for the benefit of grape growers.

JAPANESE AND ASIATIC BEETLES

In the heavily infested district damage by the Japanese beetle was as severe as in previous years and was somewhat more widespread. Ornamental plants were severely damaged in the suburbs of Philadelphia and Trenton, and in Camden and Gloucester Counties, N. J. Field and sweet corn suffered in New Jersey and Pennsylvania, especially the so-called second planting of field corn in Bucks County, Pa. Thorough and timely

spraying with lead arsenate continued to give excellent protection on plants on which this material could be used. The protection of early ripening varieties of peaches and small fruit and of flowering shrubs must be studied further before recommendations can be made.

Several phases of the biologic and physiologic studies under way have been completed, and results have been prepared for publication. The great importance of a treatment for grubs in the soil necessitated the study of the physiological resistance of the immature stages throughout the year. This work has been completed, and the results have been used as a basis for determining the dosage of soil insecticides required by quarantine regulations at different seasons to obtain most effective destruction of the larvæ. Studies are being made on the effect on the grubs of the Japanese and Asiatic beetles of sublethal dosages of various insecticides, and also on the effect of submergence in water for various periods of time—information needed primarily in connection with treatments required by quarantine regulations. Attention is being given to the relation of local conditions, climate, etc., to the Japanese beetle. With its spread into other districts, such as Virginia, Massachusetts, and points in Maryland, these ecological studies become important and will take account of the influence on the insect of crop conditions and practices as affecting its food supply, and of soils and other factors.

In connection with investigations to develop insecticides for the protection of peaches and other early ripening fruits, thoroughgoing studies of repellent materials have been undertaken. In the course of this work a large number of compounds have been under test, and the results thus far indicate that coal tar, creosote, empyreumatic oils, phenyls, and the cyclic nitrogen compounds have repellent properties, whereas esters, ketones, ethers, aldehydes, and essential oils are likely to be attractive.

The difficulty encountered during the past few years in the manufacture of oleate-coated lead arsenate was due in part to the lack of accurate methods for determining the proportion of lead oleate present. It is believed that this difficulty will be overcome. Manufacturers should then be able to standardize their product to a greater degree than heretofore. A spray that is useful in controlling large numbers of the Japanese beetle has been developed, namely, a combination of lead arsenate and highly refined sugar sirup. Such a spray can be used very effectively on noneconomic plants when the beetle population is dense. In studies of extracts of pyrethrum it has been found that the most satisfactory extracts are obtained with pyridine, acetone, and isopropyl alcohol, and that Derris is most effective when it is extracted with coal tar, naphtha, or ethyl alcohol. Tests show that extracts of pyrethrum and of Derris are about equally effective on the beetle. Experiments indicate the control of the insect on corn by the use of a dust composed of 9 parts of hydrated lime and 1 part of powdered lead arsenate, applied early in the morning when the dew is still present on the plants.

Following much experimentation, a new type of Japanese beetle trap has been designed which has very high efficiency in capturing the insects. The principle involved will render the traps much more effective than they have been heretofore. In this connection extensive studies have been made with various types of bait in the traps, and distinct improvements have been made.

Investigational work with hot water used as a dip to destroy immature stages of the Japanese beetle has been about completed. The immersion of the roots of certain types of nursery plants for a short period has been found a simple and effective method of destroying grubs in root cavities and masses of soil. The treatment consists in heating the soil about the roots to a temperature of 112° F. and maintaining this temperature for 70 minutes. This treatment has been applied to several varieties of herbaceous plants as well as deciduous shrubs and will be of special interest to nurserymen in the infested districts.

Experiments indicate the effectiveness of naphthalene as a soil fumigant of potting soil for the destruction of the immature stages. When naphthalene flakes are used at the rate of 5 pounds, thoroughly mixed in a cubic yard of soil and left undisturbed for a week, all stages of the Japanese beetle are killed.

Extensive experiments have been conducted during the year to determine the effectiveness of lead arsenate as a soil insecticide. It appears from preliminary work that a large number of varieties of evergreens, deciduous trees, and shrubs, as well as other nursery stock, will grow in soil treated with sufficient lead arsenate to pre-

vent beetle development, and without injury to the plants. This extension of the use of lead arsenate has followed considerable experience in the destruction of grubs in lawns and golf courses, where it is used in the proportion of 5 pounds to each 1,000 square feet of turf.

Gratifying advance has been made in the establishment of parasites of the Japanese and Asiatic beetles, some 337,000 having been received during the year from bureau employees located in India and Japan. Five or six species have become well established. Some of these have spread noticeably, and their colonies have become sufficiently strong to permit the making of collections for liberation in other localities. Thus from the original colony of *Tiphia popilliavora* Rohwer, at present the most promising parasite introduced, it has been possible to collect enough of the insects to establish 25 colonies, the insects being released mostly in the suburban area around Philadelphia. It is believed that some 200 new colonies of this species can be established during the season of 1929. Four colonies of *Tiphia vernalis* Rohwer are now established in Pennsylvania and New Jersey. Additional work is being carried on with several parasites which have not as yet been established in this country. It is believed that further work will enable the department to establish several additional species in the infested area. Special effort is being made to bring in as large numbers as possible of the parasites already established in order that as many colonies as possible may be liberated throughout the range of the Japanese beetle.

Under appropriations available July 1, 1928, a thoroughgoing study has been undertaken of the freeing of plants and plant products from infestation by insects. In connection with this work a check on various methods now used in connection with State and Federal quarantine regulations is being made to determine their effectiveness, both from the standpoint of killing the insects and from that of their effects on the plants. Extensive search of literature has been made and a manuscript on methods of freeing plants from insect infestation has been prepared for publication. This will be especially useful as a working handbook for those concerned with quarantine matters. Studies have been already inaugurated to determine the effectiveness of hot water, naphthalene, carbon disulphide, and 25-meter high-frequency radio waves in destroying infestations of various insect pests on several agricultural commodities. It is hoped that during the course of this work new methods and improvements may be developed suitable for a wide range of products, especially nursery stock and imported food products now subject to regulation as to injurious insects and diseases.

CEREAL AND FORAGE INSECT INVESTIGATIONS

The work on insects affecting cereal and forage crops has been, as formerly, under the direction of W. H. Larrimer.

EUROPEAN CORN-BORER RESEARCH

The enforcement of quarantines against the European corn borer and related regulatory and control activities have, since July 1, 1928, been conducted by the Plant Quarantine and Control Administration of this department while the research activities have been carried on, as before, by the Bureau of Entomology. The European corn borer has continued to spread in the Great Lakes area at about the usual rate. In Ohio and Indiana this movement apparently was less extensive in 1928 than was the case during the previous year, owing no doubt to the intensive and thorough scouting campaign conducted in 1927, which resulted in determining the actual border of the infestation in these States. The commercial damage to the crop resulting from the work of the pest still remains small or almost negligible. Recent infestation counts, however, show unmistakably that the insect has multiplied rapidly during the last year in Ohio, Michigan, and Indiana.

The work of parasite introduction has progressed rapidly and satisfactorily in recent months, and more than 1,000,000 additional parasites, comprising nine species, were liberated, principally in the States of the Middle West, since my last report. In New England, where the introduction work has now been in progress for only 10 years, no less than nine species of introduced parasites have been recovered, several of them in considerable numbers. In this connection it should be understood that, owing to the differences in the biology of the various species, some of them multiply readily under laboratory conditions whereas others must be liberated directly without any attempt at artificial breeding. Two species of the latter class, namely, *Masicera senilis* Rond., a tachinid or fly parasite, and *Dioctes punctoria*

Roman, a hymenopterous or wasplike parasite, have now become so numerous in Massachusetts that it is expected collections can be made there in the season of 1930 for reshipment to the infested area of the Great Lakes.

In June, 1928, a competent investigator was dispatched to Japan to collect and ship to this country any useful parasites of the corn borer that might be found there and on the Asiatic mainland. The corn borer was found in practically all of Japan from Hokkaido or Yezo on the north to Formosa on the south, as well as on the mainland in the Chosen Peninsula. From this general territory five species of parasites have been collected, identified, and introduced, two of which are believed to be distinct from any of those yet found in Europe. Other species have been found in Japan that have not as yet been identified. To take adequate advantage of the prevalence of parasites in the Orient, preparations are being made to dispatch an assistant to Japan to facilitate the more rapid introduction of these beneficial insects.

In the sweet-corn-growing sections of eastern New England successful efforts have been made in recent years to lengthen the market period for the finer varieties of this vegetable by placing the ears of corn in cold storage at freezing temperatures. In this connection our investigators were called upon to determine the effect on the corn borer of the temperatures used for refrigeration in order that data as a basis for quarantine action might be available. It was determined that when the corn was kept at or near 0° F. the borers contained in it rapidly succumbed and all of the borers died after the lapse of 100 hours. This was not true of seed corn, however, in the ears of which borers frequently hibernate.

Especially significant have been the results obtained in the operation of two emergence cages, each 1 acre in extent, on the experimental farm at Toledo, Ohio, devoted to training of scouts, the development of agricultural machinery for corn-borer control, and the many phases of corn-borer research. These cages were erected immediately previous to the expected emergence of the corn-borer moths on fields in which the borer population was known, and which had been treated by approved cultural control methods such as plowing cleanly either in spring or fall. The results showed in both cases that the methods employed had killed over 98 per cent of the borers. Although these results confirm the general results obtained during the recent clean-up campaign, it is planned to repeat the experiments to eliminate any possible error.

ALFALFA WEEVIL

The alfalfa weevil continues slowly to spread toward the Mississippi Basin and is now firmly established in western Nebraska. It has just been discovered at Medford, Oreg., near the Pacific coast, only 25 miles from the northern border of California on the main line of a railroad running into that State. It seems inevitable that this pest eventually will make its way into all the principal alfalfa-growing regions of the West.

The investigation of the manufacture of alfalfa meal as a possible means of distributing the weevil, which was begun last year, is now nearing completion. The results show that when the manufacture of this commodity is conducted with proper precautions the danger of distributing the pest through commerce in the meal is very slight if not negligible. It was discovered, however, in the course of the investigations that more than one-half of 130 freight cars examined, which had contained alfalfa hay from infested regions, were infested with alfalfa weevils. It was apparent also that the weevils might remain in such cars almost indefinitely and thus be carried to almost all parts of the United States. Some of the cars investigated were traced to New York, Omaha, Portland, and Los Angeles.

There has long been a question in the minds of certain ranchers of the Great Basin whether alfalfa hay which had been sprayed with arsenicals to kill the weevil is in any way hurtful to cattle. Preparations are now under way to investigate this matter thoroughly.

LEAF HOPPERS AND ALFALFA

For some time there has been a growing suspicion among entomologists and agronomists that an abnormal and harmful condition in alfalfa commonly called "yellows" was caused by the feeding of leaf hoppers. A preliminary survey of the matter conducted by the Bureau of Plant Industry resulted in reinforcing the idea that the insects were acting as vectors of a disease, and that bureau therefore appealed to the Bureau of Entomology for aid in making a thorough investigation. A qualified entomologist was assigned to the

study of the entomological phases of the problem at Arlington, Va., beginning in April, 1928. His preliminary findings, which have just been announced, indicate that this yellowing of the alfalfa is caused principally by the feeding of a common and widely distributed leaf hopper, *Empoasca fabae* Harris. It is planned, however, to go more thoroughly into this problem in order to bring about the control or elimination of this widespread injury as well as to determine whether other factors may be concerned in the matter.

PEA APHID IN ALFALFA

Damage to alfalfa by the pea aphid and related species has been increasing for several years. The losses from this cause have been especially severe in the irrigated lands of California, Nevada, and Idaho, but a similar condition is known to exist in several States of the Great Plains where alfalfa is the principal forage crop produced. In the Antelope Valley of California losses have been especially severe, and the time of an entomologist attached to this division has been devoted principally to an investigation of this problem. Many methods of control have been tried, including dusting both from the surface and from airplanes, the burning over of infested fields with motorized burners of special design, and the practice of cultural methods based on cutting the crop at various times and handling the irrigation water in different ways. None of these methods have yet proved satisfactory.

HESSIAN FLY

The Hessian-fly situation in general remains most satisfactory from the standpoint of wheat growers. The insect is reported as at the lowest ebb of abundance that has occurred for several years in Kansas, and it is scarce in the northern half of the East Central States. A moderately severe infestation exists in southwestern Indiana, where much early sowing of wheat has been practiced recently.

A continuous record of outbreaks of this pest, kept for about 50 years in the East Central States, shows that up to 1919 there occurred more or less regularly, at intervals of from six to eight years, severe general outbreaks which usually took a heavy toll of the wheat crops. Since then, however, no such great invasion has been recorded, and it seems fair to assume that this is due in large measure, if not exclusively, to the general adoption of the control measures advocated by the department and supported by the State agricultural authorities, wherever winter wheat is grown as the main cereal crop. This general-control program, however, is made possible only by the annual regional surveys conducted by the bureau, the results of which are communicated to the various States concerned.

GRASSHOPPERS

Indications point to impending outbreaks of grasshoppers in North Dakota and many counties in Texas. The grasshopper population in the northern section of the Great Plains area has gradually increased during the last three years, until in the fall of 1928 a survey in western North Dakota indicated strongly the imminence of a general outbreak this year in that section. In an effort to prevent this invasion the bureau assigned one of its experts from the Billings, Mont., field laboratory to cooperate with the State experiment station by preparing and distributing a special publication on the control of the pest in the area affected. This was issued as Special Circular No. 1 of the North Dakota Experiment Station in March of this year.

The Texas outbreak developed rapidly during the spring of 1929 until some 17 counties were affected, extending from Matagorda along the Gulf on the south to Collin, Archer, and Motley Counties on the north and west. At this writing the staff located at the San Antonio field laboratory is cooperating in a survey of the situation.

In California during the summer of 1928 about 2,000 acres of grain were destroyed by grasshoppers in Siskiyou and Modoc Counties. This situation has been greatly improved, however, by the general use of the poisoned baits.

SUNFLOWER INSECTS

In recent years there has sprung up in eastern Missouri a rather lucrative industry, the production of sunflower seed as food for poultry. As the acreage increased in this district, the usual multiplication of insect enemies developed until an appeal for aid was made by the growers to the bureau through its local representative at Webster Groves, Mo. In compliance with this request an investigation was begun, with the result that much valuable information regarding the insect fauna of this plant has been accumu-

lated. It is planned to publish these results in the near future.

In the course of this investigation an egg parasite of snout beetles of the genus Calendra was reared in considerable numbers, and this fact was brought to the attention of a representative of the Hawaiian Sugar Planters' Association who was in this country in search of parasites for introduction there against the sugarcane borer. At his request a supply of this parasite, *Anaphoidea calendrae* Gahan, was reared and turned over to him for shipment to Hawaii.

MORMON CRICKET

As a result of the serious situation caused by the invasion of the Mormon cricket originating on public lands in Routt and Moffatt Counties in northwestern Colorado, the last session of the seventieth Congress appropriated $8,000 to be expended for the purchase of materials and poisons to combat the pest. It was understood that the farmers would furnish the necessary labor and that the State would supervise the work. The campaign is now in full swing, but it is too early to report results.

RANGE CATERPILLAR

The outbreak of the range caterpillar mentioned in last year's report is now under way in northeastern New Mexico. Owing to the cold, backward spring of the present year, the eggs did not begin to hatch until late in June, but recent reports show that a very heavy infestation is in progress and that serious damage to a million or more acres of the finest cattle ranges in the Southwest is almost certain. A trained entomologist has been stationed there temporarily to assist in introducing beneficial insect enemies and to obtain general information on the outbreak.

INTRODUCTION OF PARASITES OF THE SUGARCANE MOTH BORER

To supplement the effort at control of the sugarcane moth borer in the Gulf States by mechanical and cultural means, the introduction of insect enemies of this pest from the West Indies was undertaken some years ago. It was found, however, that the parasites occurring there apparently were not effective when removed to this country, and it was therefore decided to seek more effective parasites in South America, where climatic and cultural conditions more comparable to those occurring in the United States were known to prevail. Accordingly, an expert was dispatched in the summer of 1928 to Argentina and headquarters established at Tucuman. Since that time four species of parasites have been discovered, shipped to New Orleans, and there liberated. Apparently the most promising and abundant of these is a sarcophagid fly which is believed to be specific to the moth borer.

INVESTIGATIONS OF INSECTS AFFECTING STORED PRODUCTS

E. A. Back has directed the investigations of stored-product insects, as in previous years.

INSECTS ATTACKING GRAIN AND GRAIN PRODUCTS

An outstanding feature of the work with insects attacking stored grain and grain products has been a continuation of the investigation of insects affecting flour begun at the close of the previous fiscal year. The data obtained during the year have had to do with control in flour mills and flour warehouses, with special regard for the conditions affecting successful treatment of sacked and cartoned materials. They indicate that there is great need for a more thorough attack upon this problem than has been possible heretofore.

The field-control work directed against the weevils attacking stored corn throughout the South has continued to give gratifying results. It has further emphasized the importance of insect control in storage as a prime requisite in the production of a corn crop that will carry with it into storage a minimum of infestation. In many fields of corn growing near farm buildings, in which no attempt had been made to eliminate weevils, nearly all ears were found infested at time of harvest. In other fields of corn growing close to storage places in which systematic protection of the corn by fumigation had been practiced, or in fields distant from storage places, it was difficult to discover weevils at harvest time. This work seems to indicate (1) that if no weevils are allowed to leave bins or cribs where grain is stored, there will be no field infestation; (2) that weevils in large numbers do not fly great distances from the source of infestation; (3) that two fumigations a year, when properly done, will keep stored corn free of weevils; (4) that weevils

are being successfully and economically controlled by fumigation; and (5) that there is no insect in the South as destructive to farm wealth which can be more easily controlled.

DRIED-FRUIT INSECTS

The major activity in the project relating to insects infesting dried fruits has been the investigation of the biology and control of the dried-fruit beetle and other fig-infesting species. A survey of the insect population of fig orchards in the principal producing areas of central California was made through the use of a new type of trap and by the examination of a large series of samples of figs. Tests were made of the effectiveness of trapping for the control of the dried-fruit beetle and its allies. Trapping was only partially effective in controlling these insects and the diseases of which they are believed to be the chief vectors. The bait used—a slowly fermenting mass of cull dried peaches—was very attractive to the beetles, but did not compete successfully with the attraction offered by ripening figs. A search for more attractive baits has proved unproductive. The attractiveness of the peach bait, however, was found to be increased by allowing it to become infested with larvæ of the dried-fruit beetle.

Much new information regarding the life history of the dried-fruit beetle was obtained and offered for publication.

A survey was made of the condition of dried figs in about 75 per cent of the tonnage of all growers' deliveries at packing houses. The data obtained have been made available to fig growers through personal contacts, growers' meetings in the field, and the annual fig institute, with the result that an increased understanding of the fig-insect problem has been promoted and fumigation equipment at the plants of small fig packers considerably increased.

Experiments with fumigants for the control of dried-fruit pests, especially with reference to raisins and figs, were continued. These have included work with hydrocyanic-acid gas, isopropyl formate, ethyl formate, ethylene oxide, a mixture of carbon disulphide and carbon dioxide, and several proprietary products. Attention was given to adapting ethylene-oxide fumigation to the needs of the dried-fruit industry. Tests already completed, both in fumigation chambers and in refrigerator cars loaded with packed raisins, have given encouraging results.

The widespread occurrence of the Indian-meal moth and the fig moth in new-crop raisins was investigated. It was found that these infestations are largely the result of improper storage methods on the ranches and can be eliminated almost entirely by the grower himself by the application of known remedial measures.

FUMIGANTS

The work of developing new fumigants and of adapting them to commercial practice has been continued throughout the year.

A noteworthy development has been the discovery of a new principle in fumigation. It has been found that the lethal effect of the combination of certain gases upon insects is far greater than the effect of either one used alone. A preliminary paper on the use of carbon dioxide to increase the insecticidal efficacy of fumigants has already been published and deals with one phase of the new principle. The use of carbon dioxide in combination with other fumigants reduces the length of exposure needed to kill insects in infested products to one-third or even one-fourth of the time normally necessary without carbon dioxide, and this method gives perfect results when only about half the usual quantity of the fumigant is used. It is particularly adapted for vacuum-fumigation tests, but is also applicable for use in ordinary gas-tight vaults. Experimental work upon other phases of this principle is being completed and will be reported upon shortly.

In the early part of the fiscal year a paper was published regarding a new fumigant, ethylene oxide, developed in cooperative work between this division and the Bureau of Chemistry and Soils. Subsequent work with this fumigant has shown that it is the best gas now available for use in treating foodstuffs. It is safe to use, noninjurious to foodstuffs, leaves no odor or poisonous residue, and is very effective in killing insects. Considerable time has been devoted to determining the best methods of using this gas in the fumigation of different types of commodities, dosage tables have been worked out, and all available information regarding it has been incorporated in a paper that has been submitted for publication. Special attention has been paid to the fumigation of nut meats, which are extremely

difficult to treat successfully. Owing to the fact that nut meats absorb tremendous quantities of fumigants, special dosage schedules have had to be worked out for both atmospheric and vacuum fumigation.

Several promising new fumigants are being tested and will be reported upon shortly.

BEAN WEEVILS

During the year the large-scale experiments for the control of bean weevils in California, undertaken with the establishment of the Modesto laboratory, have been continued. This work has been made possible only by the hearty support and cooperation of the State, county, and Federal agricultural organizations operating in Merced, Stanislaus, and San Joaquin Counties. A feature of the year has been an unusually heavy infestation by the southern cowpea weevil in the section where black-eyed cowpeas are grown, and of baby limas by the common bean weevil. Notwithstanding these adverse developments, bean growers and bean warehousemen are enthusiastic over the very noticeable decrease in cash deductions made because of weevil infestation in the bean crop as a whole.

The excellent spirit of cooperation shown by growers and warehousemen has made possible, through the examination of thousands of samples taken at the time farmers deliver their crop at the storage houses, the detection and prompt reporting of evidences of infestation. Where infestation has been discovered the entire consignment of beans has been fumigated before it has been allowed storage space in the warehouse, and a thorough study has been made of conditions in and about farm buildings and fields of the farmer producing the weevily crop. By this procedure valuable facts are being obtained concerning farm conditions favorable to the production of weevily crops.

HOUSEHOLD INSECTS

Insects destructive to house furnishings, whether these are in the home or warehouse, have received as much attention during the year as limited funds have permitted. The interest of housewives, furniture manufacturers and retailers, and furniture warehousemen has continued to be much in evidence. As a result the study of conditions encouraging to the development of clothes moths, carpet beetles, and tow bugs has been continued. Special attention has been given to methods of control suitable for the housewife, retailer, and warehouseman. There has been a great increase during the year in the equipment installed by private firms for protection against this group of pests. Experiments with solutions for the protection of fabrics against the attack of fabric pests have been continued, but to date no so-called moth-proofing solution tested has rendered fabrics absolutely immune to attack.

INVESTIGATIONS OF TROPICAL, SUBTROPICAL, AND ORNAMENTAL-PLANT INSECTS

Investigations of insects injurious to tropical, subtropical, and ornamental plants have been conducted, as formerly, under the direction of A. C. Baker.

MEDITERRANEAN FRUIT-FLY RESEARCH

The most important work of the division during the year has had to do with the presence of the Mediterranean fruit fly in Florida. Immediately on the discovery of the fly the laboratory at Orlando, Fla., diverted every energy to research on the insect, and the fruit-fly laboratories in Hawaii and Mexico were called upon for assistance.

The research in Florida has been shaped on the following plan, the work being conducted under the Plant Quarantine and Control Administration: (1) The development of effective sprays for the adult flies, and a check up of these sprays as they are applied in the eradication campaign, the check-up being concerned both with the chemical nature of the materials under large-scale operations and the effect of the sprays on the trees; (2) the development of attractants for the adults and the use of these attractants in traps throughout the infested territory, thus making it possible to follow the rise and fall of the fruit-fly populations, both in relation to the application of sprays in this territory and in relation to the elimination of hosts; (3) a quantitative survey of the wild fruiting plants in the infested territory to determine the facts and possibilities of spread of the fruit fly into uncultivated areas; (4) a similar survey of cultivated fruiting plants to determine the hazards from the presence of cultivated plants not exposed to attack by the fly in other countries; (5) experiments under caged condi-

tions to determine what wild or cultivated fruits the fly will accept for oviposition if deprived of other host material; and (6) the development of methods of treatment which will guarantee susceptible fruits against the possibility of introducing infestation into other parts of the country.

The following results have been obtained: A spray formula has been developed which has proved exceedingly efficient in the eradication operations. Since the poison contained therein is lead arsenate, and since arsenicals are considered somewhat injurious to citrus trees, a substitute has been sought for. In accordance with a new theory, poison compounds have been prepared. The cooperation of the insecticide division of the Bureau of Chemistry and Soils is acknowledged in the preparation of certain of these compounds on request. The compounds prepared have proved more highly toxic to the fly than lead arsenate, and in the standard fruit-fly formula have been sprayed upon the same foliage for 37 successive days without apparent injury to trees or foliage.

Many reports of injury by arsenical spray have come to the laboratory, and these have been investigated. In every case reported to date the injury has been assignable to causes other than the spray. Very often the trees have been in a weakened condition because of attack by scale insects, lack of fertilization, or similar circumstance.

Studies on attractants have resulted in the discovery of a number of highly attractive materials, some of them many times more attractive to the fly than any heretofore developed. In this work the cooperation of the Florida State Experiment Station is acknowledged. With the use of new attractants and those formerly known, an exhaustive trap survey of all infested counties is being conducted. In this way the rise and fall of the fly population has been closely followed, and this has permitted valuable improvements in the eradication operations, both in regard to spraying and in regard to clean-up of hosts.

The study of the wild flora constitutes one of the basic features of the eradication campaign, since dissemination of the fly into the uncultivated wilds would make eradication impossible. It consists in an examination of all fruiting plants considered as possible hosts for the fly, first for possible infestation, second for fruiting period, and third for relative abundance. To date, over 300 square miles of wild territory skirting infested properties has been thus intensively studied. One hundred and sixty-one species of wild fruiting plants considered as possible hosts have been encountered, studied, and tabulated in detail in these 300 square miles. No infestation has been observed in any of them.

With this study in progress, a second investigation is under way. The entire State has been divided into floral areas, and 10 rather distinct types of plant communities have been found to constitute these floral areas. Quantitative surveys of these communities are being made throughout the infested territory and in other territories liable to infestation. This is done by marking off different blocks in these associations, each containing 10,000 square feet, and recording each individual plant in such blocks. Blocks are followed through the season to record changes therein. To date, 63 of these blocks, covering all known plant associations, have been studied. The purpose of this study is to enable the research organization to provide clean-up forces with exact data on the percentage of any plant known to be, or later determined as, a host in any type of land that it may be necessary to clean.

The study of the cultivated fruiting plants has included all cultivated plants bearing fruits which show possibilities of serving as hosts. The study to date has covered 122 species of such plants. One phase of this work has been the development of a calendar for all known hosts, showing the periods throughout the year in which these host plants are in fruit in the three districts of the State liable to infestation. This has permitted a determination of the relative hazards presented by the cultivation of these different plants in any territory likely to harbor the fly.

A second study under this project has covered the varieties of citrus fruits under commercial production, as to their distribution, the quantities produced, and the dates of maturity. Information along these lines should indicate the fly hazard in relation to maturity as well as in relation to the shipping problem. An additional assignment to this project has been the town and city surveys. Practically every city and town in 14 counties of the State has been scouted and quantitative surveys made in several of the older ones to determine the quantity of host trees existing.

Fruits of all species taken in the surveys both of wild and of cultivated

fruiting plants are exposed to the flies for oviposition purposes. Special attention is given to those plants which are of economic importance or which exist in abundance. Oviposition has been attempted in 39 of these fruits, and larvæ have been developed to maturity in 29. In other cases larvæ have been able to develop when inserted artificially into the fruits, but the adults have been unable to infest the fruits in a normal manner. Citrus varieties at different stages of maturity are also exposed to the flies in cages in order to determine at what stage of maturity these fruits will be acceptable to the fly. Fruits of the same age and variety are measured in each case for the maturity ratio, so that it can be determined at what stage of marketability fruits may be attacked.

Following studies in the Mexican laboratory, an artificial medium has been prepared in which the larvæ are able to develop and pupate. Since this medium is of known chemical composition, it permits the addition of materials to determine if pupation may be prevented, the object being to develop a material suitable for application to the various types of soil. The studies so made have been carried to the field, and soil samples have been collected from various groves, (1) from those parts of the groves where pupæ have been found in abundance, and (2) from those parts where they have been scarce. It has been found that the soil containing many pupæ has given pH readings of 6 to 8, whereas soils from those parts of the groves where pupæ were rare have given readings of about 3. Following the tree-tolerance theory on which the new insecticides have been developed, studies are under way on tree fertilization in the hope that some material may be found which, applied to the soil, will inhibit pupation of the fruit-fly maggots.

In experiments conducted at the Hawaiian laboratory, the possibility that susceptible fruits which have been exposed to certain low temperatures can be guaranteed as safe for shipment to other States has been investigated. These studies have been conducted with small equipment at the laboratory and checked in a commercial precooler in a packing plant. The infested fruit used in experimentation was, in the most extensive experiment, wrapped and given commercial pack. It was found that in fruit subjected to a temperature of 28° F. for five hours and held for four and one-half days at 30° all larvæ, even those most mature, were killed. In determining the influence of such treatment on the fruit, this bureau had the cooperation of the Bureau of Plant Industry for tests made in Washington on fruit shipped for the purpose. After the fruit had been held there at these temperatures for extended periods it showed no unusual injury.

Owing to the excessive time necessary under such a method of safeguard, and following promising results obtained from holding fruit at high temperatures in the Mexican laboratory, efforts were made looking toward the use of high temperatures and humidities for safeguarding fruit. After a series of experiments at different temperatures it was discovered that all larvæ were dead in fruit held at an inside fruit temperature of 110° F. for eight hours. In all the types of oranges and grapefruit available on the trees at the time no apparent injury resulted from such treatment as far as flavor or character of the fruit was concerned. No early fruit was available for test, and the influence of such treatment on early fruit remains to be investigated. The experiments, at first conducted on a laboratory scale, have been transferred to commercial coloring rooms, where a complete kill of larvæ has been obtained in infested oranges placed in different locations in the car lot of fruit. Difficulty, however, was experienced in adjusting the temperature in such rooms, and this difficulty remains to be overcome.

It is well known that heavy loss from stem-end rots has been experienced when coloring-room temperatures have been raised to slightly over 90° F. Higher temperatures, however, have not been attempted in coloring rooms. Counts for rots in the experiments undertaken showed a very marked reduction in the number of rots in the heated fruit as compared with the number in the unheated. These figures appear so promising that the cooperation of the Bureau of Plant Industry has been obtained in an extensive series of experiments looking toward the elimination of such rots by treatment at high temperatures. Preliminary experiments with cultures and inoculations have given very favorable results. Heat tests with avocados have also been conducted without any apparent injury to the fruit. In all tests the humidity is held very high.

At the Hawaiian laboratory tests have been conducted with different attractants advocated in other countries. Such tests can be carried on to advantage in the Hawaiian Islands, since flies are abundant there. It was discovered that the peach lure considered very attractive in Australia captured very few flies. The possibility of larvæ surviving in citrus juice was also investigated at that laboratory. This issue was raised in connection with some of the disposal practices in Florida. Two experiments were conducted, in one of which the larvæ were permitted to obtain air at the surface of the juice, while in the other this was prevented. Out of 1,447 larvæ in the first experiment, none survived over five days. Out of 7,800 larvæ in the second experiment, none survived 72 hours. Studies on the susceptibility of Guatemalan avocados have been continued. These have included studies of fruits in cages, of fruits inclosed on trees, and of fruits collected in the field. Under forced cage conditions even the thickest-skinned varieties were infested. In the field, however, out of 1,269 fruits of the Guatemalan varieties held for observation only four proved to be naturally infested. Studies of the parasites of the fruit fly have been continued, and a shipment of 3,000 pupæ made to Australia in order, if possible, to establish parasites in that country.

THE MEXICAN FRUIT WORM

Studies have been continued in the insectary in Cuernavaca, Mexico, not only on the Mexican fruit worm but on the larvæ and adults of other species of fruit flies occurring in that region.

Owing to the usual method of fruit disposal, experiments were conducted in burying to different depths fruit containing larvæ. Although no adults of *Anastrepha striata* Schiner were able to emerge from a depth greater than 9 inches, adults of the Mexican fruit worm (*A. ludens* Loew) penetrated through 18 inches of soil in several experiments. It was found, however, that many more could reach the surface when the fruits were buried in a shaded location than if they were buried in one exposed to the sun. This probably accounts for the protection afforded by burial to the 18-inch depth in the Rio Grande Valley.

With regard to the common fruit flies in Cuernavaca, namely, *A. ludens*, *A. striata*, and *A. fratercula* Wied., a series of experiments proved that the adults are attracted to trees other than those of their natural hosts even in the presence of their host trees. The mango is the favorite fruit of *ludens*, is very seldom attacked by *striata*, and is never attacked by *fratercula*, but in the adult-fly population of 40 mango trees *striata* occurred almost as commonly as *ludens*.

It is obvious from experiments conducted that current conceptions in regard to the longevity of *A. ludens* must be discarded. A length of life of seven months is easily indicated. The premating period of a series of flies emerging in January averaged 25 days, and even males were alive after five months. The egg-laying capacity of the species is also much greater than was supposed, one female depositing 298 eggs during a period of 47 days.

The work in the laboratories in Mexico City has yielded results which it has been possible to apply in the fight against the Mediterranean fruit fly in Florida. A study of the temperature tolerance of the larvæ in mango fruits showed that these could be killed in the fruits at about 110° F.

Experiments on the relation of pupation to soil acidity showed that this activity is largely controlled by the condition of the medium in which the larvæ find themselves, and that pupation may take place within the fruit if the conditions of acidity are suitable. The influence of moisture is also marked.

One very interesting study which has an important bearing on the Mediterranean fruit-fly situation was conducted in the laboratory. It was believed that the adult flies were feeding on wild yeastlike organisms which occur on the outside of the fruits and elsewhere. An artificial medium was therefore prepared, the only source of food used being cultures of the yeast carried on the legs of the flies. Adult flies were confined to this medium, and they were still alive after two and a half months, having had no other source of food but this yeast. It is evident, therefore, that fruit flies can survive for long periods feeding only on wild yeasts, and this fact must be taken into consideration in any eradication campaign. It has been found in Florida that yeasts may form an important article of diet of the Mediterranean fruit fly, since flies that were dying rapidly on sugar and water survived long periods if given yeasts.

Besides the studies carried on in the insectary at Cuernavaca and those in the laboratory at Mexico City, an ex-

tensive ecological survey of the heavily infested districts of Mexico has been conducted. Centering in Cuernavaca, the survey has covered the western slope from Tepic to Oaxaca, and on the eastern slope the area about Jalapa, Cordoba, and Vera Cruz. This survey has included a study of the climatic conditions, the character of the soils, the vegetation and fruit production, and the fruit worm and insects associated with it.

INSECTS INJURIOUS TO ORNAMENTALS

The work on insect pests of ornamentals has been conducted, as heretofore, mainly in the laboratory in New Orleans, in California, and in the Northwest. In the latter section the interest of the growers has been evidenced during the year by their erection of a first-class laboratory building at Sumner, Wash., in which the investigations may be conducted under modern working conditions. Besides containing offices, laboratories, temperature room, and photographic facilities, the laboratory plant has a large greenhouse permitting three temperatures, an insectary, and a shop. Ample ground is provided for experimental plots.

Investigations at this new laboratory are at present largely confined to work on bulb pests. One of the interesting developments of the year is the determination of a new variety of mite which lives within the bulbs, especially near the neck, the activity of which stunts and distorts the leaves. Experiments in control have indicated that the mite yields to the hot-water treatment devised for bulb flies. Fumigation studies on the control of bulb flies have been continued, particularly experiments in handling case lots of bulbs. Extensive series have been run but inconsistent results have been obtained, and an effort is now being made to determine the causes of this inconsistency. Studies in regard to field control are also under way. These have comprised some 65 field plots and a large variety of materials, but conclusions have not yet been drawn from the records.

The major work on bulbs for several years has dealt with hot-water treatment for the bulb flies. This has had two phases, one touching the flowering quality of the bulbs and the other the weight of the bulbs. It is on the second phase that the work of the year has been concentrated.

During the year the occurrence of the red spider on asparagus ferns in Florida caused heavy losses to the fern growers, and an investigation was at once undertaken covering its biology and possible control. It was determined that clean culture in the fernery and in a belt 8 or 10 feet wide around it, and two spray applications seven days apart, in which 1 part of 5 per cent Derris extract in 400 parts of water was used, would give relief.

In New Orleans, work has been continued on the development of lubricating-oil emulsions in camphor-scale control, and on certain studies of fumigation with hydrocyanic-acid gas. The fumigation work immediately in hand was planned in the hope of determining if the toxic action of hydrocyanic-acid gas bears a definite relation to its source and if different forms of cyanide are of equal value in yielding the gas. As to the first question, the cyanides of calcium appear to give a higher mortality than the other forms. And the second question, judging by the results so far obtained, appears to be answered in the negative.

PARASITES AND PREDATORS

Besides the work on parasites of the Mediterranean fruit fly, previously mentioned, two projects of the division fall under this general heading. The first is a cooperative project with the Department of Agriculture, Commerce, and Labor of Cuba, devoted to the importation of parasites of the citrus black fly into Cuba and those of the citrus white fly into the United States. This project has just been undertaken, with field headquarters in Singapore. Up to the present no parasites have been shipped, but a number are known from several regions of the Orient, and it is hoped that colonies of considerable strength will soon be built up.

The second project involves a thorough study of the influence of environment on the Vedalia beetle in order to determine the basic principles underlying the predatory relation. During the year the feeding rate was studied and was found to be a function of temperature, age, seasonal change, and sex. Observations at short intervals showed that the periodic nature of the feeding of the beetle was modified by light conditions.

INVESTIGATIONS IN CALIFORNIA

Through the interest of the citrus industry of California, a fund has been established for the construction of a modern, thoroughly equipped laboratory, the building of which is now un-

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der way. This will be one of the most up-to-date entomological laboratories in North America and will be the center of all of the division's work in the Southwest.

At present investigations on bulb flies are under way in California following the same general program as that in the Northwest. Citrus-thrips investigations have developed, in dusting with sulphur, an excellent insecticide. Continued investigation of the heat treatment for the date scale has refined the method to a point where it is hoped that in another year or two it can cover several types of conditions. A new insect, however, a mite, is becoming rather widely distributed in date gardens. This mite has been discovered not only on palms but on various species of grass and upon corn. A thorough investigation of the pest will be undertaken as soon as facilities permit.

TRUCK-CROP INSECT INVESTIGATIONS

Investigations on vegetable and truck-crop insects have been continued during the year under the general direction of J. E. Graf and W. H. White.

MEXICAN BEAN BEETLE

The addition to the territory occupied by the Mexican bean beetle occurring in the season of 1928 is probably of more importance than that of any previous year since the discovery of this insect in the eastern part of the United States. The beetle, upon reaching the important bean-growing areas in Maryland, New Jersey, and Delaware, reproduced rapidly, and there seems to be but little doubt that it will become a pest of major importance there. The beetle is now known to occur along the Atlantic seaboard from northern North Carolina to northern New Jersey. In North Carolina the beetle reached the coastal plain in at least six counties. Six counties in southern New York have become invaded, and two in Michigan. The spread to the West has been slow, no new territory having been reported as infested with the exception of four counties in northern Indiana. On the southern edge of the infested area in central Alabama and Georgia and in northern Mississippi conditions are apparently not normally favorable for the survival of the beetle, as no appreciable spread has been recorded in these sections for five years.

The increased injury by the beetle resulted in greater interest on the part of growers, particularly the canners, with the result that control measures were used much more widely than ever before. As in past seasons the most effective control was obtained by spraying with magnesium arsenate. Calcium arsenate, applied as a dust, was also effective against the insect, but in many instances, particularly in certain sections of the Atlantic coastal plain, plant burning followed treatments with this chemical, and some brands caused marked crop injury even when diluted with seven parts of lime. This development resulted in an enlargement of the program of work on insecticides. Pyrethrum extracts gave very good control of the beetles when applied at frequent and regular intervals. Tests with 18 fluorine compounds showed that barium fluosilicate was quite toxic to the insect but that it also caused severe plant injury. Several other fluorine compounds, including manganese fluoride, lithium fluoride, strontium fluoride, sodium fluosilicate, and copper fluosilicate, were toxic to the insect but this toxicity was subject to considerable variation, and rather heavy plant injury resulted in some instances. The application of remedies by commercial growers yielded encouraging results. Although poor control of the insect was apparent in a few cases and insecticidal injury appeared in others, a majority of the growers were well satisfied with the general results.

Biological and control studies were continued in New Mexico. Only one generation of the bean beetle occurs there annually, the adults spending an average of about 260 days in hibernation. It has been definitely ascertained that the most successful hibernation takes place in the yellow pine and oak zone. Above this zone the insect perishes. Control studies indicated that one treatment, properly timed, would more than pay for itself in the increase in yield of bean vines alone.

SWEETPOTATO WEEVIL

Experiments in the eradication of the sweetpotato weevil were continued in Alabama and Mississippi in cooperation with the States concerned. The work in both States has been systematized so that one general plan is followed. Scouting is conducted periodically during the year. All potato fields on infested farms are thoroughly cleaned at harvest, and all storage banks and houses are cleaned in the spring. Planting stock for the suc-

ceeding crop must be weevil free. The outstanding development of the year was the fact that no weevils were found in Baldwin County, Ala. The cleanup of this county was partially offset, however, by the finding of a new infested area in Pearl River County, Miss., comprising 16 properties. At the end of the year the infested properties for the whole area under observation were distributed as follows: In Mississippi, 19 in Pearl River County and 16 in Hancock County; in Alabama, 22 in Mobile County and none in Baldwin County. Information collected on the biology of the sweetpotato weevil indicates that this insect flies more readily than was formerly supposed. Definite records of flight, both during the day and at night to lights, have been made.

WIREWORMS

At Walla Walla, Wash., extensive rearing experiments are being made in the laboratory with eight species of wireworms commonly found in that section. The two primarily concerned in crop injury are *Limonius canus* Lec. and *Pheletes occidentalis* Cand. Approximately 87,000 eggs were placed under incubation, and from these 14,000 larvæ had been obtained up to June 30. Field studies include unit screenings of the soil to obtain data on the seasonal changes in wireworm population and at the same time readings in each field under observation as to soil moisture, soil temperature, and hydrogen-ion concentration. This phase of the work has for its object the determination of the factors favorable and unfavorable to wireworm development and damage. Control work is carried on under both cage and field conditions and includes tests with poisoned baits, contact insecticides, and soil fumigants. Where the return from the crop allows for considerable expenditure per acre good results in controlling wireworms have been obtained from the use of carbon disulphide applied directly to the soil. When it is used at the rate of 1 fluid ounce in holes 4 inches deep and 18 inches apart each way, the diffusion of gas in the soil will give a kill of the wireworms approaching 100 per cent. For best results the soil should be uniform, of loose texture, with at least 10 per cent moisture content and with a temperature above 50° F. Similar studies are being carried on at the substation at Toppenish, Wash., and field-plot experiments are being conducted to determine the influence of crops and cropping on the seasonal abundance of the wireworms in the soil.

In California continued tests with bait materials for the attraction of wireworms showed that for the first two-weeks' period wheat and beans are superior to corn or milo. Tests with aromatic chemicals in baits gave no striking results except that nitrobenzene appeared to be quite consistently repellent. Experiments with varying soil temperatures where the wireworms were free to choose the temperature most suitable to them showed the greatest concentration of worms where the soil was between 50° and 60° F. Eggs hatched and the wireworms developed in soil having a wide range of hydrogen-ion concentration.

Biological and control work on the group of sod-land wireworms, which includes the wireworms attacking corn and tobacco, is being continued at Chadbourn, N. C. Tests to determine the attractiveness of baits corroborated the findings of last year and showed that of themselves the baits or plants exhibit little or no attraction to the wireworm *Monocrepidius vespertinus* Fab., but the wireworms follow the rows where the soil has been disturbed for planting or placing of the baits. Field studies have shown that late-planted tobacco suffers only minor injuries from wireworms, but the farmers are prejudiced against late planting. Rearing work under way indicates that the species concerned in the major portion of the injury have a life cycle of at least 2 years. Studies on cropping methods have shown that the growing of either corn or cotton on the land during the two years preceding the planting of tobacco increases the chances of wireworm injury to the tobacco. Test plots to determine the effect of cropping on the population of the corn wireworm (*Horistonotus uhleri* Horn) have been started.

Laboratory tests are under way to discover a poison toxic to wireworms and one which can be adapted to poisoned baits. Various chemicals are being tested, both by injection and by voluntary feeding. Arsenites, especially sodium arsenite, proved more toxic than any other material under conditions of forced feeding. It was difficult to induce enough voluntary feeding to prove the usefulness of any of the materials tested.

POTATO INSECTS

Biological studies were continued at Chadbourn, N. C., on the seasonal life history and behavior of the seed-corn maggot as a potato pest in the field. The location and stage of this insect during the months of July and August are still undetermined. Control studies in the field were conducted on both potatoes (seed pieces) and spinach seedlings. This work included, in the case of spinach, a study of the effect of fertilization and the previous crop on maggot injury. Spinach fields fertilized with organic fertilizers or containing large quantities of humus suffered the heaviest injury from maggots. Mineral fertilizers are not attractive to the flies, and the smallest loss occurred on soil low in organic material and fertilized with mineral materials. Other factors being equal, the larval population of a soil during the breeding season seems to be directly proportional to the quantity of partially decayed organic matter that it contains. The time of application of the fertilizer was found to be of considerable influence on subsequent maggot injury. In cooperation with the Bureau of Plant Industry tests were continued on the protective effect of seed suberization prior to planting. These tests again showed that properly suberized seed was not as susceptible to the attack of the maggot and to decay as freshly cut seed pieces.

STRIPED CUCUMBER BEETLE

Experiments conducted with the striped cucumber beetle were concerned largely with the effect of food upon oviposition and comparative experiments on control with several dusts under field and cage conditions where temperature was considered in relation to the effectiveness of the material. Calcium fluosilicate gave promising kills only under conditions of high temperatures. Sodium fluosilicate killed high percentages of beetles in cages and appeared to have a marked repellent effect. This material caused plant injury in about half the tests. A calcium arsenate-gypsum mixture gave high kills of beetles in cages, but usually required from 48 to 72 hours to effect a kill. Under field conditions it appeared to be decidedly repellent, Nicotine dusts were more effective under high temperature with clear weather and low winds than when the opposite conditions prevailed. The beetles died quickly under such conditions in both cage and field tests. These tests showed that under satisfactory climatic conditions a dust containing from 2 to 4 per cent of nicotine is a satisfactory remedy for the striped cucumber beetle.

BERRY INSECTS

Further experiments with sticky screens as an index to the strawberry weevil's emergence from and location of hibernation quarters showed that the principal weevil infestation in the fields came from the first 100 feet of adjoining woodland. By careful burning of this narrow strip the spring infestation has in cases been reduced to the point where direct control of the insect with poisoned dust was unnecessary. This burning of woodlands is not advocated unless conditions are such that the fire can be confined to the area harboring the overwintering weevils. The most important cultivated food plants of the weevil in North Carolina are the strawberry, dewberry, and blackberry. The most important wild hosts are the huckleberry, chokeberry, wild blackberry, and dewberry. Survival of larvæ in cut buds is largely dependent on the stage of development of the bud and on moisture conditions. The mortality of larvæ is greatly increased in the presence of excessive or insufficient moisture.

The cyclamen mite, until recently recognized as a pest only in greenhouses, was destructive to experimental plantings of strawberries at Geneva, N. Y., the plants being greatly stunted and weakened. Several materials were tested as remedies under field conditions. Sulphur gave the best results, but the control was so slight that it can not be recommended as a remedy on the basis of these experiments. Laboratory tests were made on submerging nursery plants in hot water at 115° F. for eight minutes and in a 2 per cent white-oil emulsion at 110° for five minutes. The treatments did not seem to injure the plants, but their effect upon the mites is as yet undetermined.

Further experiments on the control of the common red spider as a pest of strawberries were conducted in Louisiana. Numerous dusts and sprays were tested, but only the former gave promising results. The sulphur dusts, both undiluted and in combination with other materials, gave the best results, and the quickness of action

and effectiveness appeared to be in proportion to the percentage of sulphur in the mixture. The undiluted sulphurs gave very good control as heretofore, both in commercial and in experimental plantings, even under unfavorable weather conditions.

SUGAR-BEET LEAF HOPPER

The life history of the sugar-beet leaf hopper has been followed in detail in southern Utah, so that data will be available for comparison with its development in previous years. Entire populations of different species of insects on the principal host plants of the sugar-beet leaf hopper have been studied on a quantitative basis with a view to ascertaining the species involved, the relative numbers of each, and the factors responsible for such relationships. Investigations of the egg parasites of the leaf hopper have revealed the hibernation places of the parasites, and data are available on their comparative numbers from various locations in southern Idaho. Studies on the insect associations of the mustards which fill one of the most important gaps in the succession of the leaf-hopper host plants in southern Idaho have been brought to the point where investigation of the competition of various insects for this plant as a source of food may be attempted.

Observations of the effect of climatic conditions on the development of the leaf hopper have been continued, with a view to obtaining data which will make possible the estimation of the possible abundance of the pest and its effect on beet culture. The growers of the Twin Falls district were informed that prospects of leaf-hopper injury for 1929 were slight, and this statement was followed by the planting of the largest acreage in the history of the district. On June 30 leaf-hopper populations were unusually low, and the chances of crop loss from this source appeared slight. In connection with the study of climatic factors affecting leaf-hopper abundance, the effects of climatic variations have been observed on other insects, notably cutworms and flea beetles, both of which rose to prominence in 1929, the outbreaks being associated with a distinctive type of winter and spring weather.

Search in Mexico for egg parasites of the leaf hopper did not reveal any species not known to occur in the United States. This investigation also established the fact that permanent breeding grounds of the leaf hopper extend over 500 miles south of the international boundary. Surveys for the sugar-beet leaf hopper in Montana confirmed the previous belief that Montana, by virtue of the climatic conditions prevailing there, will be free from economic losses due to the sugar-beet leaf hopper. Similar surveys, conducted in cooperation with the States concerned, are under way in Iowa, Texas, New Mexico, Utah, and Oregon. The work in Oregon has indicated that though certain areas are obviously unsuited for beet culture, owing to their close proximity to the leaf hopper's breeding grounds, there are, nevertheless, certain small irrigated valleys which are worthy of further study to determine their probable status as leaf-hopper-free areas.

TOBACCO INSECTS

Investigation of the life history of the tobacco stalk borer in Tempe, Ariz., has shown that eggs are laid each month of the year and are deposited singly in punctures on almost any part of the plant. A period of from 47 to 72 days is required for development from egg to adult. The adult weevils feed on any part of the plant, the tender leaves being preferred. The problem of control is complicated by the fact that the adult is easily repelled by poisoned foliage and the larvæ can not be reached by insecticides. Several wild plants are hosts and serve as a source of food supply for the insect in the absence of tobacco.

Since tobacco is treated with arsenicals for the control of insect pests, an investigation of the arsenical residues remaining on tobacco leaves at maturity was necessary. In cooperation with the Bureau of Chemistry and Soils analyses are being made of tobacco leaves taken from treated plots in the field at different periods, also after harvest and curing, to determine the quantity of arsenic remaining after handling and processing. At the same time other insecticides are being tested in an endeavor to find a substitute which can be used on tobacco without exposing the product to possible rejection on account of high arsenical residues.

MUSHROOM INSECTS

In cooperation with the Pennsylvania State College of Agriculture and the Bureau of Plant Industry of the department a study of mushroom pests and their control was inaugurated January 1. Because of the short time

this project has been active the results obtained are of a preliminary nature. The principal line of investigation followed has been the control of mushroom flies. The comparative value of fumigation with pyrethrum dust and fumigation with smoke from burning pyrethrum has received considerable attention. The objective of this phase of the work is reduction in cost of treatment with pyrethrum and increase of its efficiency through a more even distribution of the toxic agent throughout the house.

Another phase of the control work which shows promise of practical employment is the use of natural light as an attracting agent to the flies. Preliminary tests were made with glass panes inserted in the doors of the house, the inside of the doors being covered with commercial fly papers to catch the flies as they flew to the light. In one test where a 6 by 18 inch glass pane was used in each of the five doors of a heavily infested house approximately 370,000 flies were caught during a period of six hours. While it is not believed that this method alone will effect control of the mushroom flies, the indications are that it will be a valuable adjunct to fumigation.

MISCELLANEOUS

Life-history studies on the pepper weevil developed the fact that six generations may occur in southern California. The insect breeds throughout the year, both in peppers and in nightshade. The biology of the insect is similar on both plants, but mortality is higher in nightshade. Infestations as a rule were lighter the past season than during the preceding season, but because of the losses suffered by growers last year most of them resorted to dusting. Calcium arsenate continued to give the best results in controlling this insect, but its use increased indirectly aphid infestations in some sections. Nicotine dust was used for aphid control, but wind and temperature were unfavorable most of the time, and the application of improperly made dusts added to the generally mediocre results obtained in controlling the aphid. In general, spraying yielded more consistent results. The use of calcium arsenate necessitates the removal of arsenical residues before the peppers are marketed or dried. Cultural control has demonstrated its usefulness against the weevil, and the systematic cleaning up of the overwintering food sources of the weevil—that is, nightshade and old pepper fields—may make necessary only the occasional employment of direct measures against this pest.

Studies on the relation of climate to the growth of the pea vines and the development of the pea aphid are being continued in Wisconsin. The weather so conditions the plant growth on one hand and modifies aphid reproduction on the other that in the average year the plants withstand the infestation produced under such conditions without showing appreciable commercial damage except in rare instances. It appears that natural enemies are not a decisive factor in aphid control until the plants have approached near enough to maturity so that aphid reproduction on the peas has almost ceased and the infestation fallen considerably below its peak. Dusting and mechanical-control tests were continued, and the effect of these treatments on the insect, on the total yield of peas, and on the grade rate and quality of the canned product was determined. The results were comparable to those of the last three years. They brought out more clearly, however, the fact that under favorable conditions of plant growth it is not only unnecessary to attempt mechanical control of the pea aphid, but that the application of such measures may be detrimental to the crop. Studies on the relation of the insect to its environment are being continued in Wisconsin and New York.

A large series of laboratory tests were conducted on the control of the celery leaf tier to determine what insecticides might be useful under field conditions. The work with arsenicals showed that a quantity required for efficient killing of the leaf tier would leave an objectionable residue on the plants. Various fluosilicates were tested, and although the toxicity to the insect by several of these compounds was satisfactory they caused such consistent foliage injury that their use was abandoned. Pyrethrum, which had been used by growers during the last season, was found to be the only material which was toxic to the leaf tier and at the same time not injurious to the celery foliage and which also left no objectionable residue on the plants. Extensive experiments were undertaken with the object of lessening the costs of pyrethrum treatments. The result of the work showed that 50 per cent dilutions of pyrethrum with lime or sulphur were satisfactory from the standpoint of commercial control of the insect. Improvements in meth-

ods of applying the dust so as to force it into the center of the plants increased the insect kill to a marked degree. Work on rearing the egg parasites of the leaf tier for distribution in the field has been continued, but thus far difficulty has been experienced in obtaining maximum oviposition from the laboratory-reared parasites, and this has resulted in only slightly increased parasitism in the field even when relatively large numbers of parasites were liberated. An ecological study of the occurrence of the leaf tier at different stages of development of the celery crop has included a study of the predacious insects and birds which may influence the abundance of the pest.

Investigations on the development and control of the European earwig were initiated in Washington State at the beginning of the year. This insect, for some years noted as a pest in towns and cities, is showing a tendency to become an agricultural pest and is spreading into rural communities. It has caused considerable damage in market gardens by its attack upon cabbage and carrot seedlings. It hides in and feeds upon the heart of celery; beans, potatoes, and peas are eaten readily. The earwig finds its way to market in the heads of cabbage and lettuce and beneath the husks of sugar corn, making such vegetables less desirable and consequently reducing their market value. The pest occurs more abundantly in the humid districts of the infested section than elsewhere, although it has been able to maintain itself in several communities where irrigation is practiced. Experiments with poisoned baits are under way, but extensive trials under different conditions will be required to demonstrate those of greatest value.

In the Gulf region the vegetable weevil has continued to spread, and 27 additional counties are known to be infested. Its known distribution in the Gulf region is as follows: Alabama, 19 counties; Florida, 3 counties; Mississippi, 50 counties; and Louisiana, 13 parishes. Biological investigations have shown that the weevil flies more readily than had been supposed, and it is apparently by this method that local spread occurs. The list of host plants has been increased by the discovery that it is able to live on several additional wild plants. Estivating adults have been found in numbers under the loose bark of pecan trees. The insect feeds readily on several baits prepared from some of its preferred foods; but on first appearing from estivation, the beetle shows for a few weeks a slight preference for growing plants. In California the extended cold weather during the season of 1928–29 delayed the development of the vegetable weevil, with the result that there was less damage than usual to susceptible crops.

INSECTICIDES

Physiological studies are under way to determine the effects of various poisons on certain insects. The influence of injections of several poisons on the gaseous exchange of the Colorado potato beetle has been studied. Another activity dealt with the study of enzymes found in the digestive tract of insects, their effect on the solubility of arsenicals, and the possible inhibiting effect of the arsenic on enzyme activity. Work is also under way on the determination of the distribution of arsenic in insect tissues. A method is in process of development which will make such a study possible and may be of considerable value in indicating more exactly the manner in which arsenic kills.

COTTON INSECT INVESTIGATIONS

B. R. Coad has continued in charge of investigations of insects affecting the cotton plant.

The boll weevil continues to dominate the cotton-insect investigations of this bureau, although during the year there has been considerable enlargement in the studies devoted to other insect pests.

BOLL WEEVIL

The hibernation studies on the boll weevil as listed in previous reports have been continued with some slight expansion. The 14 cooperating agencies have somewhat increased the scope of their work, and in the investigations of this bureau new points have been added to represent sections which were not included in earlier records. Still further expansion of this sort is needed and contemplated. The reports issued on these hibernation observations have been considerably curtailed and now include only those data which past records have shown to be of most significance in the prediction of weevil activity.

The dusting-machine investigations have largely centered around improved machinery and technic. The develop-

ment of dusters with high air velocity has permitted the construction and introduction of entirely new types which are making it possible to dust much more cheaply and under more adverse conditions than in the past. New types based on these principles are now appearing on the market at prices considerably lower than those of older models and with a greatly increased efficiency. These same principles are being applied experimentally to duster attachments for cultivators, and equipment is now being tested and designed for the various types of riding and power cultivators. In addition, a survey is being conducted to determine the needs of various districts for machines of these types. In conjunction with these machine developments, the swath tests of all types are being continued, a simplified, more rapid form of test being utilized which has evolved from the elaborate swath-width observations of the past several years. The efficient swath rating for each type of machine has been determined for the older standard types and is being determined for the new types as they appear. Special attention has been devoted to the so-called cloud-drift method which has received considerable publicity during the last two years. A number of machines have appeared on the market which blow out large quantities of dust and allow this to drift across the field so that swaths from 300 to 500 feet in width can be treated. Careful tests of such dust clouds have shown a very heavy wastage due to overdosage close to the machine and an irregular, inefficient dosage through the remainder of the swath.

The studies of weevil flight have been combined with the investigations of chemotropism which had progressed in the laboratory far enough to show certain materials as attractive to the weevil in laboratory tests. These materials are now being tested in the field-flight studies in the effort to determine whether or not they can be made attractive under field conditions. Results of the past studies on migratory flight indicate that in the territory around Tallulah, La., there is much less relation between the distribution of cotton planting one year and the resultant infestation with weevils the following year than had been previously supposed. This is very important in connection with any attempts at weevil control in the fall, such as fall destruction of stalks and fall poisoning.

The plat tests at Tallulah have been continued on a reduced basis and have consisted largely of tests of new or improved insecticides and the standard series of weevil-damage tests. The series of these weevil-damage tests completed in the fall of 1928 showed some of the largest gains from poisoning which have been secured in the 13 years these tests have been running, these gains averaging 390 pounds of seed cotton per acre with a maximum gain of 1,542 pounds of seed cotton per acre.

The cooperative investigations in the State of South Carolina have been continued with some enlargement. The plat tests on early poisoning are being continued and a standard series added to check the amount of weevil damage under various conditions. In addition, the weekly report on weevil activity throughout the State is provided for the use of the State authorities in issuing timely advice on weevil control.

The similar cooperation with the State of Oklahoma is being continued and enlarged. The control tests are new conducted at three stations—Ada, Hugo, and Muskogee. Results of these control tests for the growing season of 1928 indicated that under the conditions of that season the methods developed elsewhere throughout the South gave most profitable results. However, it is necessary to continue these tests for a few years so that they will show the effects of seasonal fluctuations. The results for the season of 1928 have been published by the Oklahoma station.

COTTON FLEA HOPPERS

Investigations of damage by cotton flea hoppers have continued to center around the more technical, fundamental studies, although close observations have been maintained in many sections of the South for the purpose of following field conditions and damage. Six different species of insects have now been incriminated, and a report has been prepared describing the type of injury produced by each. In addition, considerable progress is being made on a technical study of the nature of this injury and its possible causes. Investigation of direct control has centered largely around a study of the nature of the toxic action of sulphur on the insects and the factors influencing it. So far these continue to point to the importance of high temperatures and bright sunshine immediately following an application.

ARIZONA WEEVIL

Studies of the adaptation of the Arizona weevil to cultivated cotton have been continued at the isolated ranch. Weevils have now been carried through four years since they were removed from their wild host plants and have been started on their fifth year with the complete record of their life history and biological activity, especial attention being given to any modifications or changes in habits which seem to be developing. A manuscript has been submitted summarizing all of these studies to date. The survey on distribution in nature has been completed as far as the United States territory is concerned, and a report is in course of preparation. In addition, the regular studies on activity and distribution in cultivated cotton have been maintained. These show a continued increase in infestation in the southern Santa Cruz Valley and a gradual spread and increase to the northward in this same valley. No new infested districts have been reported within the year.

PINK BOLLWORM

The organization of pink-bollworm research as described in a previous report has been still further expanded. A research laboratory has been installed at Presidio, Tex., and various sublaboratories, including one in the Laguna district of Mexico, are in operation. At all of these an effort is being made to build up a complete picture of the life history and habits of this insect with special reference to those features which are of primary importance in control or eradication. During the year an extensive study was made on the flight of this insect, including an airplane expedition to the Laguna district of Mexico. It was found that while moths have no tendency toward flight or activity above the plants through most of the season, they become very active about September 1, and individuals were collected at all altitudes up to 3,000 feet. These records, combined with the infestation and trap-planting records, give strong indications of the importance of wind carriage as a means of movement of this pest.

Special attention is being devoted to the question of host plants and the possibility of this species perpetuating itself on those host plants other than cotton which have been recorded in the past. So far specimens have been carried through the winter on both okra and a wild Hibiscus found in Mexico, but summer reinfestation has not been established.

A new project of cultural control has been undertaken in cooperation with the Division of Agricultural Engineering of the Bureau of Public Roads. This includes a study of plowing equipment and methods combined with irrigation processes to determine those methods which are most effective in killing off overwintering individuals.

Recent observations have directed particular attention to the gin as a concentration point for pink bollworms and to the importance of destroying the individuals present in the gin trash. Consequently another cooperative project with the Division of Agricultural Engineering has been inaugurated, and all possible variations of three basic methods of gin-trash disposal are being studied. These methods include incineration, sterilization, and milling. The studies cover relative effectiveness of the different methods as well as costs and specifications for necessary equipment. These will be used as a basis for definite recommendations and regulations for the pink-bollworm territory. In addition there has been a growing appreciation of the importance of the gin as a concentration point for boll weevils and other cotton insects and evident willingness on the part of many ginners to install equipment to render the gin trash free of such pests. Consequently it is hoped that the equipment which is being developed primarily for the pink bollworm can also be utilized throughout all sections of the Cotton Belt where pests are important.

COTTON BOLLWORM

The cotton-bollworm investigations have now been reorganized and placed on the same basis as those on the pink bollworm, all studies in the State of Texas being carried out in full cooperation with the experiment station of that State. These include a study of the influence of modern farming practices on bollworm infestation and the possibility of direct control measures, as well as studies on the relation of bollworm damage to cotton-louse infestation and weevil-control measures.

INSECT MIGRATION

At the end of the season of 1928 a review was made of the records which had been obtained on insect activity in the upper air. It was found that

while many important data had been obtained, it was necessary to revise this work on a basis of more regular observations supported by more complete records on meteorology, as it had become evident that some meteorological factors which had not been previously considered were quite important. Consequently this work is now based on regular collections at specified times and altitudes on an all-year-round basis, to give a complete picture, and is being supported by a very thorough series of ground records.

MISCELLANEOUS

In addition to the foregoing major problems, the usual amount of attention has been devoted to the other insect pests which have required investigation from time to time. The most important of these has been the cotton leaf worm, and special studies have been conducted with the view of determining the relation between intensive poisoning of the early generations which have just migrated into southern Texas and the later-season infestation in other portions of the Cotton Belt. Evidently the increased poisoning activities in southern Texas are having a very important effect in reducing the extent and severity of migrations of leaf-worm moths. Important outbreaks of other pests, particularly webworms, cutworms, grass worms, etc., have been noted and studied and advice for control given wherever possible.

INVESTIGATIONS OF INSECTS AFFECTING MAN AND ANIMALS

This work has been continued under the direction of F. C. Bishopp, as formerly.

SCREW WORMS

Various lines of experimentation with reference to the screw worm and other blowflies which attack livestock have been continued in Texas. The chemotropic responses of these flies have been given considerable attention, and further studies have been conducted with repellent materials with the hope of finding some substance which will give more complete and lasting protection of wounds against blowflies.

Tests to determine the value of systematic trapping in screw-worm control, under range conditions involving about 150 sections, have been continued, in cooperation with the Texas Agricultural Experiment Station and local groups of ranchmen, and further evidence has been found that where such trapping is properly conducted a material reduction in screw-worm losses can be brought about. In order to increase the efficacy of traps, intensive studies are now being made of the relationship between the number of flies caught and the location of the traps with reference to shade, water, habitations, topography, etc. Different types of flytraps are being tested under field conditions, including a large box trap which has been developed in the course of the work and which it is thought will be well adapted to range conditions, as it will require less frequent servicing than the smaller conical traps now generally used.

Investigations of parasites and predators of the screw worm and other blowfly larvæ have been begun, and methods of making the natural enemies of these insects more effective are receiving consideration.

CATTLE GRUBS

Additional funds provided for work on cattle grubs during the year have enabled the bureau to undertake some new lines of investigation. A laboratory has been established at Fargo, N. Dak., near the center of a district which has remained free of cattle grubs despite frequent introduction of these insects into it. It is felt that if the factor or factors responsible for this natural control can be determined they may be utilized in combating the pest in other parts of the country. All factors which may have a bearing on this problem are being carefully studied, including the chemical and physical condition of the soil, drainage, soil temperatures, climatic conditions, farm practice, parasites, diseases, and predators. Inquiry into the distribution of the northern cattle grub indicates that this species has become widely scattered in Idaho and that it is now more generally present throughout the Northwestern States than when a similar survey was made several years ago.

The area-control operations begun in Prowers County, Colo., and Knox County, Ill., by the Bureau of Animal Industry have given an opportunity for investigating the flight habits of the two species of warble flies and to test on a considerable scale some of the insecticide treatments which in previous work have been found effective against the larvæ in the backs of the cattle. This cooperative work

with the Bureau of Animal Industry has been conducted with headquarters at Galesburg, Ill.

Further experimental work has been done with insecticides applied to the backs of the cattle, special attention being given to tobacco powders of high nicotine content and dusts containing nicotine sulphate, free nicotine, and rotenone and other materials extracted from Derris root. These insecticides show high toxicity for cattle grubs and can undoubtedly be developed to a point where they can be extensively used in control procedure.

SHEEP SCAB MITE AND GOAT LOUSE

Investigation of these parasites of sheep and goats have been continued in cooperation with the Texas Agricultural Experiment Station at Sonora, Tex., and at the Dallas, Tex., laboratory. The incubation period of the different species of goat lice has been determined and the developmental period required in each case has been determined under certain conditions. Both of these points are of distinct importance in connection with the question of the interval between dippings. A number of different insecticides, especially in the form of dips, have been tested against goat lice. Among these the very fine sulphur dusts are most promising. They are very effective in destroying the lice, and no injury to the mohair or animal is apparent.

FLY CONTROL UNDER FARM CONDITIONS

Investigations of methods of meeting fly problems under practical conditions on the farm have been continued in cooperation with the Bureau of Dairy Industry at the Beltsville, Md., farm. The practicability of controlling the horn fly, house fly, and stable fly by means of proper manure disposition, the use of kerosene-pyrethrum extract as a spray, and the operation of flytraps has been further demonstrated.

EYE GNATS

The eye-gnat problem became so acute in the Coachella Valley, Calif., that provision was made in the second deficiency bill for an investigation of that pest. The eye gnats (a species of Hippelates) are present in annoying numbers in many parts of the South, but for some unknown reason they have become extremely abundant in the Coachella Valley. They are apparently important factors in the transmission of pink eye and trachoma, and conditions with regard to such diseases have been rather serious, especially among school children. The presence of the gnats has interfered materially with farm operations and has tended to shorten the period when winter residents could comfortably remain in the infested areas. The breeding habits of eye gnats are not known, and to find the source of the hordes of these insects is one of the principal problems. It has been found that the Hippelates breed under several different conditions, though their exact host relationships have not been determined. This work is being done in cooperation with the California Agricultural Experiment Station and the Coachella Valley mosquito-abatement district. The problem is being studied in valleys adjacent to the Coachella and in Arizona and Texas for the purpose of correlating eye-gnat abundance with climatic conditions, soils, crops, and agricultural practices.

MOSQUITOES

Studies of the biology and habits of anopheline mosquitoes were continued at Mound, La., especially with reference to the measurement of the effect of various ecological conditions on larval development and abundance. These studies indicate a large degree of adaptability on the part of the mosquito to its environment.

Further studies were made with reference to the use of the airplane in controlling malarial mosquitoes under swampy conditions. In this work a test was made of the effect of airplane distribution of Paris green over all important mosquito-breeding places within a radius of 1 mile of the village. The breeding areas were dusted at regular intervals throughout the summer, the results of the dusting being noted in these areas and counts being made to determine the abundance of adult mosquitoes within the village. Although it was further demonstrated that under satisfactory flying conditions Anopheles larvæ can be controlled in a given area by the use of Paris green distributed by airplane, it was found that the work did not materially reduce the number of adult Anopheles in the village, presumably because of the limited breeding area under treatment. This work would also seem to show the necessity for treating the breeding places of malarial mosquitoes over a radius greater than 1 mile from a point which it is desired to protect. In connection with this work, studies

were made of the relative efficacy of different carriers used with Paris green in airplane dusting. The relative toxicity to several kinds of mosquito larvæ of various brands of Paris green and other poisons was determined under laboratory conditions. On account of the fact that an application of Paris green is effective in destroying only those larvæ which ingest it soon after an application, as the poison neither sinks in nor is otherwise dispersed, studies have been made in an effort to develop a poison which would be less easily wet by the water, which would retain its toxicity longer, and which would remain on the surface of the water for a considerable period after application.

In a continuation of the studies of the use of pyrethrum sprays against adult mosquitoes it was found that a home mixture made by soaking 1 pound of pyrethrum powder in 1 gallon of kerosene for a period of 72 hours gave a spray as effective against mosquitoes as any of the proprietary products tested. In tests of pyrethrum powder as a larvicide against Anopheles it was found that 1 part of pyrethrum powder to 25,000 parts of water by weight was necessary to effect Anopheles control, while 1 part of pyrethrum to 44,000 parts of water gave effective control against Culex. The use of this material in open bodies of water is further limited by the fact that it is very toxic to fish when applied in quantities sufficient to control mosquitoes.

A partial survey of the mosquito situation in Florida was made last summer, in cooperation with the Florida State Board of Health. It was found that the principal species causing annoyance in the inland lake region of the State was *Mansonia perturbans* Walk. Since this mosquito is also an important pest in many other parts of the country, and since no effective control measures have been developed, and little is known about the life history of this species, some investigations of the biology and control have been begun.

INVESTIGATIONS OF INSECTS AFFECTING FOREST AND SHADE TREES, INCLUDING THE GIPSY MOTH AND THE BROWN-TAIL MOTH

The research work pertaining to the gipsy moth and the brown-tail moth, formerly under the direction of A. F. Burgess, was transferred to this division at the beginning of the year. The work of the division, as now enlarged, has continued as formerly under the direction of F. C. Craighead, C. W. Collins being in field charge of the investigations relating to the gipsy moth and brown-tail moth, with headquarters at the bureau's laboratory at Melrose Highlands, Mass.

PINE BARK BEETLES

The destruction of western yellow pine timber in southern Oregon and northern California, discussed in the last annual report, continued with increasing severity during the spring and summer of 1928 but declined markedly in the fall of the year. The annual survey of this district revealed a total loss for the year of 261,860,000 board-feet of merchantable timber, valued at over $1,250,000. In addition to furnishing information on control to the owners concerned, these surveys are expected to give valuable information on the periodicity of outbreaks of the western pine beetle and the relation of these to climatic cycles and the concomitant fluctuations of tree vigor and resistance. Control operations are still being carried on by private timber owners, the Forest Service, and the Office of Indian Affairs on portions of the worst-infested units.

A serious epidemic of the western pine beetle in the pine forests on the Modoc National Forest, in northern California, which threatened to wipe out from 25 to 50 per cent of the stand, was met by the Forest Service, on the advice of the Bureau of Entomology, by a sale of the infested unit to a lumber company. The contract provided for the control of the beetle through logging or burning the infested material, and for salvaging the timber before deterioration. During the fall of the year the Bureau of Entomology cooperated with the Forest Service and the private operators in supervising the marking of infested trees to be removed in the control program. The company cleaned up the infestation on 17,000 acres during the fall and winter, and will be required to extend control operations to 30,000 acres during the next season. Control operations on a large scale were also carried on during the winter of 1928–29 by the Forest Service and Office of Indian Affairs in southern Oregon, involving an expenditure of about $35,000. An equal amount will be expended by private timber-owning corporations in the same district.

Research work during the year has distinctly advanced our understanding

of the factors involved in the western pine-beetle problem. Considerable attention was devoted to study of the influences, aside from artificial control work, which affect the abundance of this bark beetle. It has been found that under endemic conditions the slower growing trees are selected for attack, and that epidemics usually develop where the stand contains an exceptional number of slow-growing trees as a result of overstocking, drought, or defoliation. A study now under way of the characters of both susceptible and resistant trees, including physiological differences, will enable us to recognize these reserves of timber especially liable to heavy bark-beetle losses. It will then be possible to protect such stands by the initiation of control work at the first sign of an insect outbreak or by cutting out the susceptible trees through selective logging.

The management of western yellow-pine stands offers the most promising means of eliminating losses from this bark beetle. An experiment in marking and logging an infested area was carried out on a small scale on the Modoc National Forest in 1927, where all susceptible trees were cut. Results were checked in 1928, when it was found that the volume of beetle-killed timber was 40 per cent less than it was on adjoining areas.

Considerable progress was made during the year on the study of insects predatory upon the western pine beetle. It was found that the most important predator, *Enoclerus nigriventris* Lec., often migrates in considerable numbers during the late larval period to the soil around the base of the tree and that large numbers of these predators can be saved by preventing the burning of the stump and surrounding ground cover in control work.

The intensive investigations for the development of more economic and effective methods of combating bark-beetle outbreaks within the lodgepole-pine stands in the northern Rocky Mountains were continued during the past season. This work was located on the east fork of the Bitterroot River in Montana, where an extensive outbreak of this insect exists. Tests have been made of several methods of artificial control, some of which show promise of being economically successful, while many others have been eliminated as ineffective.

Control operations within the Big Hole Basin in Montana were again carried out by the Forest Service under the technical supervision of the Bureau of Entomology during the season of 1928. This project was started in 1926 for the purpose of preventing the spread of a serious epidemic of the mountain pine beetle in lodgepole pine and yellow pine, which for several years had been spreading south along the Continental Divide and which now threatens valuable commercial and æsthetic timber stands in adjacent national forests and in the Yellowstone National Park. This outbreak has resulted in the destruction of great quantities of timber. From 40 to 60 per cent of the lodgepole and yellow pine stands on many hundreds of square miles has been destroyed. Because of the magnitude of this infestation, it was necessary, in conducting this project, to adopt what is known as the barrier plan of control, selecting the Big Hole Basin as a zone of defense in which all infested trees were to be treated each year as long as any reinfestation occurred. This departure from the usual method, requiring the treatment of all the infested trees, made this project merely experimental, as no assurance of success could be given. It was hoped that the Continental Divide would act as a partial barrier to the spread of the beetles from the solid blocks of infestation in the Bitterroot Valley into the zone selected for defense and that it would prove possible to protect the valuable timber stands to the south by holding this area against the southward spread of the epidemic. Approximately 65,000 trees were treated in 1928 at a cost of about $95,000, and the result was a very thorough clean-up of all infestation within the region. During the subsequent summer, which was apparently an extremely favorable one for the spread of these insects, the beetles crossed the Continental Divide and swept into the zone of defense in such numbers that control work in this area had to be given up.

In planning future control work advantage will be taken of the fact that there is a rather wide strip of timberless country lying a few miles to the south of the Big Hole Basin which it is hoped will prove to be at least a partial barrier to the southern movement of this epidemic.

During the season of 1928 the Forest Service conducted two projects, under the general supervision of the Bureau of Entomology, to combat outbreaks of the mountain pine beetle within the white-pine stands of the

Kootenai National Forest in Montana. The results were satisfactory. A general increase in the activity of this insect throughout the white-pine stands of northern Idaho and Montana, however, threatens to result in serious losses of timber unless the many incipient outbreaks which now exist are controlled.

INSECT PROBLEMS IN THE NATIONAL PARKS

A forest-insect survey conducted in the Yosemite National Park showed that the red turpentine beetle was seriously injuring many of the finest yellow pine trees on scenic and recreational sites. A special study of the situation was made, and control measures were recommended.

A special survey of Crater Lake National Park in September, 1928, showed that a heavy epidemic of the mountain-pine beetle had developed on areas near the western boundary of the park and was advancing toward the areas near the administrative headquarters, where control work was completed in 1927. Approximately $17,000 was utilized by the National Park Service for control work, which was started in May, 1929, and completed shortly after July 1.

PROBLEMS UNDER INVESTIGATION IN EASTERN STATES

Cooperation with several of the Forest Service experiment stations was continued as in past years, the very limited resources permitting work on only a few of the most urgent problems, in the Lake States, in the Northeast, and in the Southeast. Progress on specific problems is reported below.

During the year the work on the spruce budworm has been confined to the collection of data on an extensive series of sample plots in northeastern Minnesota. These plots are located in an area where an infestation of this insect has been in progress for the last few years. The purpose is to show the progress of events during and following an outbreak, and to determine in so far as possible the factors involved in starting the outbreak and in bringing an infestation to a close. The infestation is now at an end, and one more field season will close this project as a major activity. Conclusions can not be drawn concerning this study until the data have been fully analyzed.

The jack-pine sawfly has been studied on a series of sample plots in and near Itasca Park, Minn. This species has not appeared in epidemic numbers during the last few seasons because of the controlling effect of weather conditions, and that of disease, which appears to be correlated with weather.

The larch-sawfly investigations in Minnesota and Wisconsin were continued during the past season and sufficient data were compiled to enable the following conclusions to be drawn:

This insect, which has only 1 male to 25 females, reproduces parthenogenetically, at least in part.

The larch sawfly is much more susceptible to high temperatures than most insects.

The development of the new growth at the time of oviposition has a distinct effect upon the number of eggs deposited by each female sawfly.

Insect predators and birds are relatively unimportant in reducing the numbers of the sawfly. Mice are extremely important and destroy on an average, in all swamps examined, over 60 per cent of the cocooned prepupæ.

Insect and fungous parasites are decidedly variable in effectiveness, but are seldom an important factor. Occasionally, however, they are very effective.

The quantity of food required to bring a larva to full growth has also been measured.

The work of introducing parasites for the control of the very destructive pine tip moth at Halsey, Nebr., showed very encouraging results during the past season. The parasite *Campoplex frustranae* Cushman, which was established two years ago, has taken hold and has increased at a remarkable rate, raising the parasitism of the tip moth in the areas where it has become established from about 20 to over 50 per cent. If this parasite continues to increase, its beneficial effect in reducing the injury of the tip moth should soon be noticeable.

In the vicinity of Asheville, N. C., a series of tests were made to determine the effectiveness of several sprays on locust-borer infestation in black locust. Mortalities of from 95 to 99 per cent were obtained with emulsions of sodium arsenite, orthodichlorobenzene, and paradichlorobenzene. It is planned to continue this work for one or two seasons longer to determine which of these sprays is most effective under all conditions.

The study, in cooperation with the Bureau of Plant Industry, on the interrelation of certain blue stains of the genus Ceratostomella and the southern pine beetle has brought out some very interesting results which may materially alter our conceptions of the pine-beetle problem. Inoculations with cultures of these fungi demonstrated that the fungi alone are capable of killing the trees and gave

further support to the theory, previously held, that the beetles inoculate the tree with these blue stains, which in turn kill the tree and afford suitable food for the development of the beetle broods. Work on this problem will be continued through the next year.

INSECTS AFFECTING FOREST PRODUCTS

Tests of wood preservatives for both crude and finished forest products, as well as poisons for wood pulp and fiber products, to prevent insect attack, have been continued. Many additional preservatives have been placed under test in Panama. In addition, in cooperation with the Forest Products Laboratory of the Forest Service, four sets of timbers, each set impregnated with 14 different preservatives, have been shipped, respectively, to South Africa, Australia, Panama, and Hawaii, where entomologists of the various local governments will make yearly examinations and report on how these preservatives protect the wood from attack by termites. During the year an inspection was made in Panama of the tests under way, and important modifications were made in the method of testing preservative treatments to protect wood from dry-wood termites. In cooperation with the National Committee on Wood Utilization and the American Wood-Preservers' Association, centers for the retailing of timber impregnated with standard chemical preservatives have been advocated, and wood suitably treated is now available for purchase by the small buyer.

To supplement the tests of wood preservatives termite-proof buildings have been built entirely of timber impregnated with standard chemical preservatives, or of termite-resistant woods common in the United States. A recent inspection of these buildings in Panama shows that to date they are proving satisfactory.

A mill-scale study on southern Appalachian hardwoods was undertaken in cooperation with the Forest Products Laboratory of the Forest Service. Only chestnut and oak were found to be subject to severe injury by insects. Black locust was also infested, but not enough timber was available for study to arrive at any definite conclusions. Poplar appeared to be relatively free from injury. Defects in chestnut lumber were caused principally by the timber worm *Melittomma sericeum* Harris, while those in white oak, and chestnut oak in particular, were caused by the pinhole borer *Corthylus columbianus* Hopk. A characteristic stain accompanies the pinhole injury, which increases the area of the defect. These defects caused a lowering of the value of chestnut and chestnut oak lumber from one to three grades. No direct loss was due to culls. In chestnut only the No. 1 common and the "sound wormy" grades were affected.

SHADE-TREE INSECTS

Studies on the control of the boxwood leaf miner by fumigation have been brought to a close during the year, and a part of the results of these experiments has been embodied in a manuscript. Some work has been undertaken to assist the forest entomologist of Maine by cooperation in the control of the birch leaf-mining sawfly, *Phyllotoma nemorata* Fall., now very abundant in New England. A large number of requests for advice on insects affecting shade trees and hardy shrubs have been handled.

Studies of the life history, economic importance, and control of insects injurious to trees of special value for ornament, shade, and recreation were continued. A study of one species was completed and published as Technical Bulletin No. 83, The Pacific Flathead Borer.

GIPSY MOTH AND BROWN-TAIL MOTH

The foreign work relating to the gipsy moth has included field investigations in Hungary, Yugoslavia, Austria, Czechoslovakia, and Poland, biological studies on certain of the parasites of the gipsy moth and the satin moth, and the shipment of parasites from these central European countries to the gipsy moth laboratory at Melrose Highlands, Mass. Two entomologists have conducted this work, with headquarters at Budapest, Hungary. A total of about 180,000 parasites were shipped from Yugoslavia, Hungary, Austria, and Poland during the summer of 1928. Approximately 3,000 of these were *Hyposoter disparis* Vier., the remainder comprising various species of tachinid flies. Biological investigations are also being conducted at the laboratory in Budapest, Hungary, in an attempt to gain more pertinent information on the host relationships of the parasites attacking these hosts in Europe.

In addition, 30,000 cocoons of the oriental hag moth, *Cnidocampa flavescens* Walk., were received from Japan in the spring of 1929. At the time of the preparation of this report

the parasites had not yet emerged from this material, but dissections indicate parasitism of about 30 per cent by a species of Tachinidae.

During the year over 3,575,000 parasites have been liberated in the infested area in the United States, over 3,500,000 of them being the egg parasites (*Schedius*) *Ooencyrtus kuvanae* How. and *Anastatus disparis* Ruschka. One of the important liberations was that of *Phorocera agilis* R. D. in large numbers from overwintering material received from Europe in the late summer of 1928. Liberations were made of fertilized females which deposited eggs upon gipsy-moth larvæ.

Recovery was made in the summers of 1927 and 1928 from two locations of a species of Apanteles, a parasite introduced in 1927 on the satin moth.

Collections from many parts of the infested territory indicate that the parasitism of the gipsy moth by the egg parasites *Anastatus disparis* Ruschka and *Ooencyrtus kuvanae* How. has slightly increased over that of the previous year. All the larval and pupal parasites also showed an increase, namely, *Compsilura concinnata* Meig., *Sturmia scutellata* R. D., *Apanteles melanoscelus* Ratz., and the predatory beetle *Calosoma sycophanta* L.

The Calosoma beetle trap was further developed during the year, and some amazing records were obtained with reference to population—as many as 65 and 52 adults of *Calosoma sycophanta* L. being trapped on each of two trees during the season and as many as 4,216 per acre in one location. Further studies are being made to note the effect of removing beetles from overpopulated areas and liberating them in new territory where the gipsy-moth infestation is light but increasing.

The parasitism recorded generally from brown-tail moth larvæ in the winter webs was about the same as that of the previous year, while the parasitism among the summer larvæ showed an increase.

In the summer of 1917 a bacterial disease of the gipsy moth, *Streptococcus disparis* Glaser, was introduced from Japan and liberated in the field by R. W. Glaser, who was then conducting investigations on the diseases affecting this host. Specimens of larvæ were found dying in the field in the summer of 1928 and, when examined, were determined as having died from this disease. Further investigations are being conducted to determine the prevalence, distribution, and economic importance of the disease.

It has been observed for some years that hibernating satin-moth larvæ are affected, sometimes to high percentages, by a fungous disease. Some preliminary investigations this year have shown that two species of fungi are present, the species encountered being both parasitic and saprophytic on insects. They are (*Sporotrichum*) *Beauveria globulifera* Speg. and a species of Isaria.

Spraying tests with lead arsenate, with fish oil as a sticker, are being continued with the object of further reducing the dosage of poison required to kill gipsy-moth larvæ. The dosage has been reduced from 6¼ pounds to 5 pounds per 100 gallons of water, with 4 ounces of fish oil to each pound of poison.

Experiments conducted this year indicate that good control may be expected by spraying with a solution of 3 pounds of lead arsenate in 100 gallons of water when the gipsy-moth larvæ are very small, and with a solution of 4 pounds per 100 gallons when they are half grown to near full grown, fish oil being used in all cases at the rate specified above. Promising results have also been secured in spraying for the satin moth, using 5 pounds of lead arsenate to 100 gallons of water and 20 ounces of fish oil. This application, made during the first two weeks in June in New England, when the larvæ are about half grown, kills the larvæ, and enough of the poison is held on the foliage to effect efficient control of the newly-hatched larvæ feeding in August and September. So far as is known, this practice of using one poison spray to kill two generations of a foliage insect with one application is new in the United States.

Dusting experiments have been continued during the year with the idea of developing a sticker for poison dusts. Among the materials tried were fish oil (17 per cent by weight), ferric oxide (15 to 25 per cent), aluminum oxide (25 per cent), and a special proprietary sticker dust. All these materials showed promise and are being tried on a larger scale.

Studies of injury to foliage resulting from the action of arsenates on the leaf suggest that much of the calcium arsenate and lead arsenate breaks down on the acid leaf surface in the presence of dew, fog, and rain. When lime is added to arsenates which are dusted or sprayed on the foliage, con-

siderable leaching out of the arsenates results.

Toxicity experiments were also conducted to ascertain the quantity of foliage eaten by the various larval stages of the gipsy moth in relation to the concentration of the arsenical. Analysis suggests that a considerable part of the arsenic passes through the digestive tract unchanged, much more being found in the digestive tract than in the remaining tissues. The quantity of food eaten was almost in inverse ratio to the quantity of arsenical deposited on the foliage, and the time required to kill varied inversely with the quantity of arsenical.

Defoliation by the brown-tail moth was extensive in southeastern New Hampshire and a small portion of southwestern Maine in 1928, as for several years preceding, but indications are that it is slightly less extensive in that section in 1929. Several small local infestations still exist in the coastal region of Maine and in the eastern section of Massachusetts.

The area affected by the gipsy moth in New England in 1928 was formidable: 142,774 acres was estimated to be from 75 to 100 per cent defoliated, and an additional acreage of 119,740 was rated as from 10 to 75 per cent defoliated, a total of 262,514 acres. The amount of defoliation for 1929 has not yet been estimated, but indications are that it is extensive.

BEE-CULTURE INVESTIGATIONS

The work of the bee-culture laboratory has continued under the direction of James I. Hambleton, with headquarters at Somerset, Md.

BEHAVIOR OF BEES

The use of the Watson method for the artificial insemination of queenbees has continued with further success, and several improvements in the technic have been made. Two papers have been submitted for publication dealing with the success achieved with the Watson method at the bee-culture laboratory.

Several thousand biometric measurements of worker bees have been made, and these will be used in an effort to determine the physical differences between different races and varieties of races of honeybees. This work will be continued until all of the principal races and varieties have been measured, and will be carried on in conjunction with the work in genetics, in which artificial insemination will be used to make all necessary matings. So far special attention has been given to the Cyprian and Carniolan bees. In obtaining some of the material for these studies the electric incubator has been used with considerable success for the incubation of queen cells.

Apparatus has been installed for exposing bees to ultra-violet rays to ascertain the effect on egg laying, behavior, etc.

A paper dealing with the results of package-bee investigations in 1926 and 1927 has been prepared and will shortly be submitted to the department for publication.

The work on the reaction of honeybees to light has been continued. The acuity of brightness discrimination of honeybees compared to that of humans has been investigated. It was found that under the conditions of the experiment many bees distinguished between two small areas illuminated with white light when one was reduced to 70 per cent of the intensity of the other. Human beings were found to be considerably more sensitive, being able usually to distinguish between the same two areas when one was made 80 per cent as intense as the other, and often when the one was made 90 per cent as intense as the other. The work on the relative stimulative efficiency of the different colors in the spectrum, heretofore confined to the visible spectrum, indicates that bees may respond to ultra-violet in a way quite different from human beings. With new apparatus this problem is to be investigated further. A manuscript in three parts dealing with the reaction of bees to light has been submitted for publication.

Another season's data have been secured on the flight activity of honeybees, which will be used in correlating flight activity with various weather factors. Duplicate equipment for automatically recording the flight activity will be installed at each field station of the division to ascertain whether there is any constancy in the reaction of bees to identical weather factors in different localities.

PHYSIOLOGY OF BEES

The study of the longevity of individual bees has been continued. The mortality of package bees is the subject of a study in which temperature, available space, type of cage, kind of food, age of bees, and effect of ship-

ping are being given particular attention. The longevity of queenbees in confinement is also being studied.

DISEASES OF BEES

Investigations dealing with septicemia of the honeybee have been continued, and a paper treating of certain phases of this disease was submitted for publication outside the department.

As a result of recommendations appearing in a number of bee journals advocating the use of formaldehyde gas for disinfecting combs infected with American foulbrood, investigations to determine the merits of the gas for this purpose were undertaken. It was found that beekeepers were not warranted in using the gas under the conditions recommended largely by amateur investigators. Serious losses were reported as a result of the use of formaldehyde gas, and in some cases attention was called to the fact that beekeepers needlessly installed expensive equipment for sterilizing combs with this gas. It was found that under proper temperature conditions dry uncapped combs could be sterilized with formaldehyde gas with relatively little trouble and expense, but that brood combs containing sealed brood cells required a long exposure. The work as a whole has not progressed sufficiently to warrant recommendations, although in response to inquiries beekeepers have been warned to uncap brood combs before subjecting them to the gas and, what is of more importance, to remove all honey. When combs wet with honey have been treated with the gas, then aired thoroughly and later given to the bees, heavy mortality has resulted. Honey retains the formaldehyde even after long intervals of exposure to the air and remains decidedly poisonous to bees. It seems probable that formaldehyde gas may eventually be used to sterilize supercombs as a precautionary measure to eradicate any possible source of infection that may exist outside the brood chambers. Two preliminary papers on this subject have been written for publication outside the department.

The routine work of examining samples of brood has been continued during the year, over 900 samples having been diagnosed. A change in the method of reporting diagnoses has been made. Hitherto it was the custom to forward to beekeepers, sending samples diagnosed as American foulbrood, a copy of Farmers' Bulletin 1084, Control of American Foulbrood, in which the shaking treatment is recommended. The office now merely notifies the beekeeper as to the diagnosis, referring him to the State inspector for further advice as to the method of eradication. Since several States now make it compulsory to burn material infected with American foulbrood, this manner of notifying the beekeepers was adopted so as not to run counter to the recommendations made by these States. It has likewise been planned to place more emphasis on burning as a means of American foulbrood control in future publications on this disease. Until burning was adopted by some States very little progress could be noticed in the eradication of the disease. All adult bees received are examined for the mite *Acarapis woodi*, the cause of Isle of Wight disease, but so far the mite has not been found in this country. During the year only 54 queenbees were imported into the United States from foreign countries.

BEEKEEPING REGIONS IN THE UNITED STATES

The study dealing with the cost of honey production and apiary management, which was started last year in cooperation with the Bureau of Agricultural Economics and beekeeping specialists in the States where the studies are being conducted, was actively continued during the year. Labor records and expense statements, as well as the methods of apiary management of some 40 cooperators in the intermountain States, were carefully studied. In all nearly 28,000 colonies were included in the survey. A preliminary report showing the progress of the first year's work has been submitted and approved for publication as a multigraphed circular. In preparing this account of the work for publication it was purposely planned to refrain from making specific recommendations as to methods of management because it was felt that the work should cover a longer period before this was done. The reports of the first year's work are intensely interesting in that they show, for instance, a variation in the cost of producing extracted honey ranging from 2 cents to 22 cents per pound. The work also plainly indicates that the average beekeeper can materially increase his profits by systematic and businesslike management of the apiary work. Arrangements have been made with some of the original cooperators to continue keeping records for a period of three years more. Plans are now being made for the expansion of

this work in other beekeeping regions where conditions are different from those in the intermountain States. This work also will be done in cooperation with the Bureau of Agricultural Economics and with the beekeeping specialists of the various States. Active work will begin this fall in the white-clover belt.

The phenological work on honey plants has been continued. It is being carried on largely through correspondence and will necessarily require several years for completion.

During the year American exporters of honey have suffered considerable loss in having shipments of honey to Germany refused at the ports of entry because they were alleged to be low in diastase. In some instances these shipments were allowed to enter, but only to be used by the baking trade, and in these cases the exporter was forced to accept a lower price. In order to minimize this loss, arrangements were made with the Bureau of Agricultural Economics, in cooperation with the Bureau of Chemistry and Soils, to conduct chemical tests on all lots of honey for which official certificates of grade were asked. Lots of honey that are given certificates will be tested for diastase and the presence of invert sugar, so there should be no question as to their acceptance by German buyers. Educational material is also being prepared for transmittal to Germany through the Bureau of Agricultural Economics, showing methods of honey production and the manner in which honey is handled in this country. Assistance was also given to some of the honey exporters who experienced difficulty in having shipments of honey accepted by the customs officials of France. Analyses by French chemists indicated adulteration with invert sugar. It was found that the honey had not been adulterated, although it was probable that it had been overheated. These shipments were eventually accepted. Samples of honey from the entire United States are being collected to be analyzed by the Bureau of Chemistry and Soils for the diastase content, as well as for other ingredients. Assistance is also being given to this bureau in collecting other samples which will be used in an intensive study of North American honeys.

DEMONSTRATIONS IN BEEKEEPING

It has been necessary to continue the refusal of invitations from beekeepers' organizations throughout the country to assist at their meetings. Many requests are made that members of the staff attend these meetings, but it is possible, because of lack of personnel and funds, to participate in only a few. Assistance has been given in helping maintain a beekeeping exhibit at the National Museum, where bees are kept in glass observation hives. This exhibit has a great educational value and is one of the most popular exhibits in the museum. The equipment other than the bees was furnished through the kindness of some of the supply manufacturers. A number of observation hives were prepared and loaned for school and laboratory use. Short manuscripts, photographs, and other educational material on bees have been furnished to the press and to feature writers.

INTERMOUNTAIN LABORATORY

The work dealing with the spread of infectious bee diseases, primarily American foulbrood, has been continued in an isolated apiary located in the Medicine Bow National Forest, 14 miles east of Laramie, Wyo. Here a very interesting observation was made, namely, that the bees unassisted entirely cleaned up the disease in a number of colonies experimentally infected with American foulbrood. Ordinarily this disease is supposed to be curable only by drastic treatment. The observations made indicate the necessity for studying the behavior of the various strains of *Bacillus larvæ*, the causative organism, as well as the question of immunity, the behavior of various races of bees towards this disease, and the effect of high, dry altitudes on the life history of the organism. Because of the unexpected developments regarding the disease in this region it has been impossible to arrive at definite conclusions as to the minimum inoculum necessary to infect a normal colony. Efforts to devise methods for demonstrating the spores of *Bacillus larvæ* in honey have been continued, and while it has been found possible to do this with honey having an abnormal number of spores, no simple and reliable method has yet been found for examining commercial honeys on a routine basis. A series of culture studies have been practically completed dealing with the determination of the minimum number of spores necessary to inoculate an agar-slant culture medium to obtain germination and growth. It was found that the quantity of the initial inoculum had

a pronounced effect on the incubation period of *B. larvæ*.

The work on the flight range of the honeybee was continued in a section of the Penrose bad lands, east of Powell, Wyo. In this experiment bees were placed at varying distances from the source of nectar, which made it possible to learn exactly how far the bees from the various colonies had to fly to obtain nectar. Rather surprisingly, it appears evident from this experiment that colonies located in and at the edge of the source of nectar do no better than, if as well as, colonies placed farther away. As a matter of fact, there was but little difference in the average amount of gain for colonies located within the nectar source and those 5 miles away from it. The optimum flight range was approximately one-half mile from the source of nectar. This particular experiment is being repeated in the hope of ascertaining why colonies at the source of nectar gain no more than those some distance away, since the location of an apiary with respect to the source of nectar is of considerable importance in commercial practice.

Studies on methods of wintering in the intermountain States were continued during the year at experimental apiaries located in the yards of commercial beekeepers, where large numbers of colonies for observation were available and where various methods of packing are being tried. Indications point to the early granulation of honey in the combs as being one of the serious causes of winter losses. There is no indication from a study of the available statistics that winter losses are being reduced. They still continue to take an annual toll of 10 per cent or more of the bees in the United States.

SOUTHERN STATES LABORATORY

The Southern States bee-culture field station was established at Baton Rouge, La., on July 1, 1928. A cooperative agreement entered into between the Louisiana State University and the United States Department of Agriculture made available to the Government without cost excellent laboratory quarters, with heat, light, water, and janitor services furnished. Besides this, a nominal fund was set aside by the university for the purchase of material and equipment for the station. The station workers are becoming familiar with beekeeping practices in the Southern States, where the problems cover a wider field than those found in most of the principal beekeeping regions of the United States. The production of package bees and the rearing of queen-bees are very important and distinct beekeeping activities in the South in addition to honey production.

Because of the large areas of nectar-producing plants available in the Southern States, and the potentialities existing there for honey production, a thorough study of the nectar sources has been initiated. The progress of this survey will be slow, as it will be necessary to ascertain the limits of the principal nectar-producing plants over a wide territory, and to make detailed observations on the behavior of these plants in secreting nectar in their natural habitats, before commercial honey production can be put on a sound basis in the Southern States. It is not at all uncommon for beekeepers to be ignorant of the source of nectar from which the bees make honey. At present there is practically no information available on the subject of southern honey plants.

In an effort to reduce the losses annually sustained by express companies and buyers of package bees the department has been asked to recommend an ideal package, together with sound instructions for shipping, care of the package on arrival, etc. Undoubtedly the sale of package bees in the North to replace winter losses and make increase would be much greater if purchasers could be guaranteed the safe arrival of shipments. Until this can be done the growth of the package-bee industry in the South will necessarily be slow and subject to considerable fluctuation. Questionnaires have been sent to producers of package bees, and a first-hand study is being made of the methods of production and shipment. In arriving at a standard cage it will be necessary also to specify methods of handling and filling, care of the package prior to shipment, and the quality of the bees, including such factors as age, race, and sex.

TAXONOMY AND INTERRELATIONS OF INSECTS

A number of important activities, grouped under this division, are carried on under the direction of the chief of bureau. These include, among others, investigations in taxonomy, insect pathology and morphology, bioclimatics, and the insect-pest survey.

TAXONOMY

Work on identification and classification of insects, a large share of

which is of the continuing type, has gone forward during this year much as in past years. Owing to the transfer of S. A. Rohwer from the taxonomic unit to the position of Assistant Chief of the Plant Quarantine and Control Administration, the administrative supervision of this unit has been in the hands of Harold Morrison.

During the year a large amount of time in all the projects has been given to the proper arrangement and organization of the collections in order to put them into condition which will permit of their satisfactory use for reference, identification, and study purposes. Considerable progress has been made along these lines, but much remains to be done before this work is completed.

During the year 11,446 identifications have been made for the various offices of the bureau, for the Department of Agriculture and other governmental departments, and for State workers and private individuals in this country and abroad. As shown in Table 1, this represents a reduction in the number of identifications made as compared with the record for the fiscal year 1928.

TABLE 1.—*Identification of insects by the Bureau of Entomology for various agencies*

Order	Identifications, 1927–28	Identifications, 1928–29
Hymenoptera	1,742	2,227
Coleoptera	2,880	2,251
Lepidoptera	2,662	1,974
Diptera	1,706	1,548
Orthoptera and Neuroptera	577	626
Ectoparasites and small orders	864	588
Hemiptera	607	567
Coccidae	2,200	1,692
Total	13,238	11,473

So far as the determinations for the fiscal year 1929 have been analyzed, this reduction appears to be due entirely to a lessening demand for identifications of extremely common insects collected by the inspectors of the Plant Quarantine and Control Administration (formerly the Federal Horticultural Board).

No changes have been made in the organization of the projects which were established during the fiscal year 1928.

In addition to the identification work, mention may be made of various developments in connection with the different projects.

COLEOPTERA

Through a special arrangement whereby the Bureau of Entomology furnished compensation for work performed, all of the available specimens of beetles belonging to the subfamily Rutelinae of the coleopterous family Scarabaeidae have been sent to Friedrich Ohaus, Mainz, Germany, a world authority on this group of insects; he has made authoritative identifications for practically all of the specimens sent to him, and these have been returned. This subfamily contains a large number of important economic species, such as the Japanese and Asiatic beetles and many others, and it is consequently very advantageous to the bureau to have available for reference these authoritatively identified specimens. When Doctor Ohaus's work is completed it is expected that the National Museum collection will be able to obtain, through exchange, additional species belonging to this subfamily which are not now represented therein.

An extensive paper on the genus Agrilus was published during the year.

LEPIDOPTERA

During the year the museum received on permanent deposit a very extensive collection of Lepidoptera from the Brooklyn Museum, and the bureau workers have been engaged in incorporating this collection in the collections of the National Museum.

Under a special assignment one of the workers on this order of insects devoted two and a half months during the year to a trip to Guatemala to investigate the reported occurrence there of the European corn borer. He has also continued his studies of the Phycitinae.

Systematic monographs covering the species of two subfamilies of moths have been prepared, and one of the specialists has worked for the entire year on a monograph of the American species of the economically important family Tortricidae; this paper is now approaching completion.

DIPTERA

The bureau's specialist on fly larvæ has recently had to handle the mosquito collections, although this has left him less time than he should have for other work. The discovery of the Mediterranean fruit fly in Florida in the spring of 1929 has greatly increased the number and importance of

the calls upon him for identification of the immature stages of Diptera.

HYMENOPTERA

Aside from routine identification work, considerable time has been spent on a critical study of the species of the genus Trichogramma in an effort to establish definitely the identity and synonymy of the species belonging properly in the genus. This work will undoubtedly prove of considerable interest to economic entomologists because of the progress which is now being made in the breeding of Trichogramma for artificial parasitization of the eggs of various economic insects. Studies of various groups of Ichneumonidae have been continued.

ECTOPARASITES AND MITES

In connection with the work on mites, much time has been devoted to the completion of a study of the classification of the feather mites, which was begun by another worker some years ago.

COCCIDAE

A monographic classification of the Margarodidae was issued during the year, and work is being continued in the organization of the collections and notes in such fashion that critical studies can be pursued whenever time permits.

CREEPING ERUPTION AND CANINUM DERMATITIS

The investigations made during the past few years by G. F. White and W. E. Dove on creeping eruption and those recently made by them on caninum dermatitis, which were carried out by this bureau on an understanding with the Bureau of Animal Industry, have been brought to a close. Creeping eruption is a disease of the human skin caused by infective larvæ of the hookworm *Ancylostoma braziliense*, which infests dogs and cats. Observations on the common dog and cat hookworm, *A. caninum*, have shown that larvæ of it, too, can invade the human skin and cause itchy papular lesions that resemble early symptoms and lesions of creeping eruption. The advancing linear lesions that characterize later stages of creeping eruption, however, have not occurred in experimental infections with *A. caninum*. Several papers relating to these investigations were published during their progress, and another has been prepared and accepted for publication.

INSECT PATHOLOGY AND MORPHOLOGY

Work on problems relating to the diseases of insects that were being studied by G. F. White during the preceding year has been continued. Increased attention has been given to the polyhedral diseases. It is expected that the work on potato-beetle septicemia will soon be sufficiently rounded out so that a manuscript report on the disease can be submitted.

The results obtained by R. E. Snodgrass in the study of the morphology of various types of insects are of importance to entomologists generally and have a special bearing on toxicological experiments. Reports have been issued, entitled "The Morphology and Evolution of the Insect Head and Its Appendages," "The Mind of an Insect," and "Some Further Errors of Body-Wall Nomenclature in Entomology." A manuscript is ready for publication on The Thoracic Mechanism of a Grasshopper and Its Antecedents, and papers are in preparation on How Insects Fly and on The Sucking Apparatus of Hemiptera, Lepidoptera, Hymenoptera, Diptera, etc.

BIOCLIMATICS

Research in bioclimatics has been carried on since July, 1923, at the bureau's field laboratory located at Mineralwells, W. Va., under the direction of A. D. Hopkins, with one assistant. The plan of procedure in the work has been to develop fundamental laws and practices relating to the phenomena of life, climate, seasons, geographical distribution, etc., as affecting local, regional, or continental agriculture and other human interests, which will be of use to the specialists in other branches of science; and to investigate and verify by general and specific tests cognate systems and methods. Most of these results are more or less new in original viewpoint and in methods of development, interpretation, and application. This work has now progressed to a stage where it is believed that a manuscript on bioclimatics may in the near future be prepared for publication.

INSECT-PEST SURVEY

The insect-pest survey has now been functioning eight years and from its inception has been under the direction of J. A. Hyslop.

Cooperative arrangements for carrying on this work are in operation in all States having organized entomological activities. By informal arrangement information is obtained concerning entomological conditions in Haiti, the Hawaiian Islands, the Dominion of Canada, and Mexico. Exchange is made of information about outstanding features with the Dominion of Canada, Mexico, and the Hawaiian Islands, which have local surveys patterned along the lines of the insect-pest survey of the Bureau of Entomology.

In addition to issuing the Insect Pest Survey Bulletin, which during the year completed volume 8 and the first four numbers of volume 9, totaling 568 pages, the survey has functioned in supplying detailed distribution records to offices and field stations of the Bureau of Entomology and to the Plant Quarantine and Control Administration.

The work of incorporating in the files the statistical data on both North American and foreign insect pests from literature has progressed as rapidly as possible with the personnel available. The survey files now contain about 78,000 notes representing 3,200 genera.

The project inaugurated last year of cross indexing the entire records under the host-plant names is now approximately half completed. This phase of the work will be of considerable value to taxonomists in determining insect larvæ from unusual host plants or from regions with which they are not familiar, because, when this work is completed, it will be possible to ascertain immediately all of the insects that have been recorded as feeding on a given plant in any country or State.

During the year the survey encouraged and assisted in the organization of State surveys in three of the Middle Western States. This work has been highly successful, even more so than was anticipated. Aside from the benefits felt by the entomological departments of the States themselves, it has augmented the mass of material which the Federal insect-pest survey is receiving from these States. The success attending the organization of State surveys demonstrates the practicability of establishing such work even where practically no additional funds are available for that purpose, as the work can be made incidental to the regular routine of the office.

One of the Middle Western States, which has very extensive and complete records over a long period of time, has made all of its back records available to the Federal insect-pest survey, and the work of copying these records and placing them in our permanent files is well under way.

During the year a technical assistant was added to the personnel of the survey, and he is bringing together climatological, geological, geographical, and botanical data to be used in attempting to explain the distribution and periodical abundance of insect pests.

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